SCIENCE 7

Module 4 Structures and Forces

Learning Technologies Branch

Alberta LEARNING

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Module 4: Structures and Forces
Student Module Booklet
Learning Technologies Branch
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The Learning Technologies Branch acknowledges with appreciation the Alberta Distance Learning Centre and Pembina Hills Regional Division No. 7 for their review of this Student Module Booklet.

This document is intended for	
Students	✓
Teachers	✓
Administrators	
Home Instructors	
General Public	
Other	

You may find the following Internet sites useful:

- Alberta Learning, **http://www.learning.gov.ab.ca**
- Learning Technologies Branch, **http://www.learning.gov.ab.ca/ltb**
- Learning Resources Centre, **http://www.lrc.learning.gov.ab.ca**

The use of the Internet is optional. Exploring the electronic information superhighway can be educational and entertaining. However, be aware that these computer networks are not censored. Students may unintentionally or purposely find articles on the Internet that may be offensive or inappropriate. As well, the sources of information are not always cited and the content may not be accurate. Therefore, students may wish to confirm facts with a second source.

Welcome to SCIENCE 7

Module 1 Interactions and Ecosystems

Module 2 Plants for Food and Fibre

Module 3 Heat and Temperature

Module 4 Structures and Forces

Module 5 Planet Earth

Contents

Resources

Textbook

To complete the course, you need the textbook *ScienceFocus 7*.

Multimedia

Attached to Module 1 of this course is a CD titled *Science 7 Multimedia*. This CD contains multimedia segments designed to help you better understand particular concepts presented in this course. Ask your teacher or home instructor if you need help using this CD.

Materials and Apparatus

A list of materials and apparatus is given on page 10 of each Student Module Booklet. These items are needed to complete the module. Some of the materials and apparatus may be provided at your local school lab. If you don't have access to a school lab, you will need to get the loan kit. Talk to your teacher for more information.

Before You Begin

Organize your materials and work area before you begin: Student Module Booklet, textbook, notebook, pens, pencils, and so on. Make sure you have a quiet area in which to work, away from distractions.

Because response lines are not provided in the Student Module Booklet, you'll need a looseleaf binder or notebook to respond to questions and complete charts. It's important to keep your lined paper handy as you work through the material and to keep your responses together in a notebook or binder for review purposes later.

Refer to the Planning Ahead page for directions on what you need to do before you start this module.

Icons

This is one of five Student Module Booklets for Science 7. As you progress through this module, you will meet several icons.

Do Ahead

Some preparation must be started well ahead of the activity or investigation.

Teacher or Home Instructor

The teacher or home instructor should be contacted for help, approval of some procedure, or checking answers.

Assignment Booklet

Work needs to be done in one of the Assignment Booklets.

Safety

You must be very careful when you see this symbol.

Textbook

A reference is made to *ScienceFocus 7*, the textbook accompanying this course.

Internet

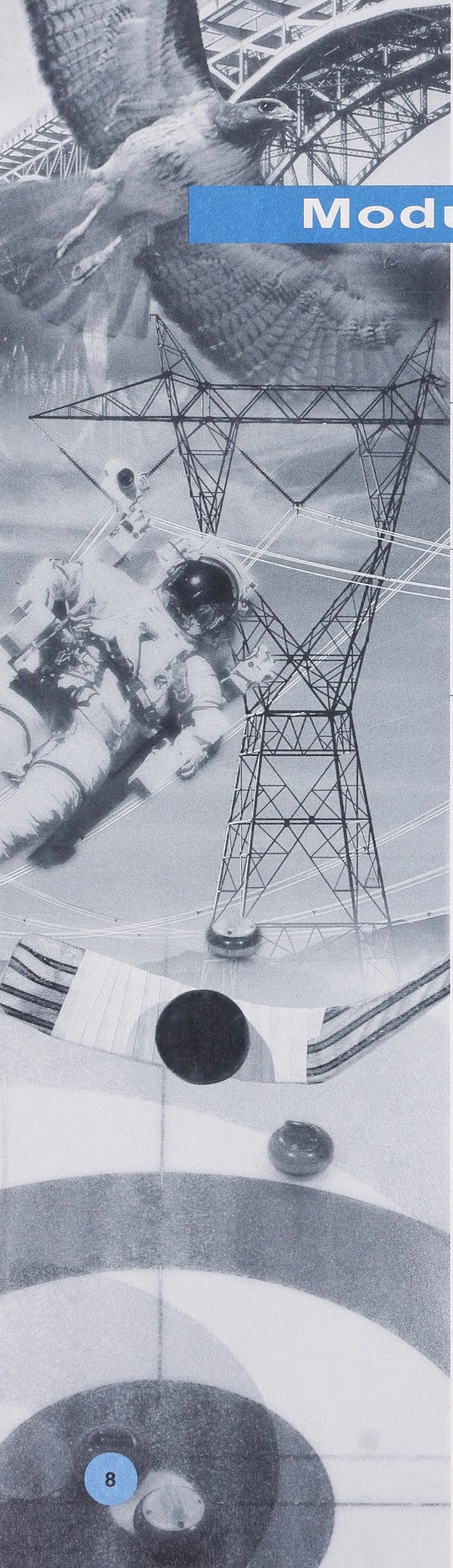
This is a reference to the Internet. **Note:** Any Internet website given is subject to change.

Multimedia

This is a reference to the *Science 7 Multimedia* CD.

Overview

Module 4 Structures and Forces



Section 1
Design and Function

Section 2
Explaining Structural Strength

Section 3
Making Structures Strong and Stable

View the city and mountains from the Calgary Tower; walk across the High Level Bridge in Edmonton; enter a high-rise building; or simply relax in your living room. In these activities you depend on structures designed for strength and stability. Your life depends on them.

The pictures on pages 266 to 269 of the textbook show several structures. Why are they designed and built in this manner? What materials are they made from? How strong and stable are they? You depend on and use human-made things every day. There are also structures in the natural world. Just think of a spider web. This module deals with both human-made and natural structures.

Structures have many purposes and a wide range of forms. You will explore the properties of construction materials and test materials under different loads and forces. Both will help you learn about structures. You will then look at various ways structural parts can be put together. You will analyze the forces involved and look into factors that affect structural strength and stability. Later, you will compare older construction methods to those used today. Lastly, you will see how science and technology have worked together. In tandem, they have led to safe and more efficient designs.

Assessment

This booklet is the Student Module Booklet. It will show you, step by step, how to advance through Module 4: Structures and Forces.

This module, Structures and Forces, has three sections. Each section is built of lessons. Within the lessons, there are readings, investigations, activities, and questions for you to do. By completing these lessons, you will

- discover scientific concepts and skills
- develop a positive attitude toward science
- practise or apply these new concepts and skills

There are suggested answers in the Appendix of this Student Module Booklet. They provide you with a way to check your understanding. Your teacher will also provide you with feedback on your progress throughout the module.

At several points in this module, you will be directed to the accompanying Assignment Booklets. Your grading in this module is based on the assignments you submit for assessment. In this module you are expected to complete three section assignments and a final module assignment.

The mark distribution is as follows:

Assignment Booklet 4A	
Section 1 Assignment	35 marks
Section 2 Assignment	34 marks
Assignment Booklet 4B	
Section 3 Assignment	24 marks
Final Module Assignment	27 marks
TOTAL	120 marks

Planning Ahead

Here is a list of materials and apparatus you will need to complete this module.

Section 1

- ❑ golf ball
- ❑ 15 small paper clips
- ❑ 20 large, thick, plastic straws
- ❑ 60 cm of masking tape
- ❑ magnifying glass
- ❑ scissors
- ❑ an empty, open-topped container (e.g., 1-L coffee tin)
- ❑ several brands of facial tissues (including one- and two-ply)
- ❑ 600–800 pennies (or washers)

Section 2

- ❑ 10 straws
- ❑ paper clips or pins
- ❑ 2 pairs of scissors (1 dull, 1 sharp)
- ❑ 250-mL plastic (or Styrofoam®) cups
- ❑ 30 cm of tape
- ❑ piece of wood (15×20 cm)
- ❑ assorted objects for weight
- ❑ force meter
- ❑ 4, 30-cm lengths of material (e.g., thread, fishing line, tape, paper)
- ❑ 5 large marshmallows
- ❑ assorted masses of known weight
- ❑ black, non-permanent felt pen
- ❑ graduated cylinder (or measuring cup in mL)
- ❑ water
- ❑ newspaper
- ❑ paper
- ❑ 2 plastic buckets with handles
- ❑ rubber gloves
- ❑ 2 desks or tables
- ❑ a strong wooden or metal bar
- ❑ ruler
- ❑ sand
- ❑ 3 or 4 shell structures (e.g., ice-cream cone, plastic cup, egg shell)
- ❑ small towel or washcloth
- ❑ toothpicks
- ❑ 2 pieces of blue polystyrene (10×15 cm)

Section 3

- ❑ force meter
- ❑ modelling clay
- ❑ 35 plastic straws
- ❑ 2-speed hair dryer
- ❑ 4 wooden dowels (of different diameters)
- ❑ sand
- ❑ assorted masses of known weight
- ❑ glue
- ❑ heavy cardboard
- ❑ index cards (20×13 cm)
- ❑ masking tape
- ❑ nail
- ❑ 250-mL Styrofoam® cup
- ❑ recipe cards (10×15 cm)
- ❑ paper plates (or index cards)
- ❑ paper clips
- ❑ pins
- ❑ flat plywood (20×20 cm)
- ❑ small tray or plastic container
- ❑ 200-g mass
- ❑ sandwich bags
- ❑ scissors
- ❑ fork
- ❑ thread
- ❑ string
- ❑ pencil
- ❑ graph paper
- ❑ ruler

If you have access to the Internet, you may want to check out some of the links for this module ahead of time. Go to the following site:

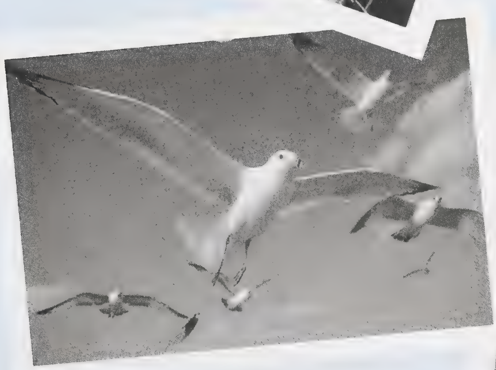
http://www.mcgrawhill.ca/school/booksites/sciencefocus+7/student+resources/toc/index.php

Section 1

Design and Function

You can see structures pretty much anywhere—for example, on a walk in the desert, on a drive over a bridge, or with a glance upward at some gulls. The cactus bloom, the bridge, and the wings of a gull are all structures. As you would expect, they have different purposes. Structures are built of many materials and appear in a wide range of forms. To see why certain materials and shapes are used in a structure, you need to know its purpose.

In this section you will classify and describe structures. This will let you see how the properties and functions of structures are related.



Lesson 1: Types of Structures

Miguel: Hey Mikaila! How was your weekend?

Mikaila: It was great! We went to the Columbia Ice Fields and saw a hang-glider flying around the valley.

Miguel: Cool!

Mikaila: Yeah. It kept circling around, diving down toward the ground, and then floating up again. It was really neat. It looked just like a hawk looking for food.

Mr. Casey: I couldn't help but overhear you compare a hang-glider to a hawk. That's a great comparison, Mikaila! The shape and function of the wings of a hang-glider are very similar to that of a hawk or other soaring bird.

Structures may have similar shape and function, but they differ in origin. Some are found in nature, and some are human-made. In this lesson you will group structures based on their origin and form.

Turn to page 270 of the textbook and read the introductory paragraphs of "Topic 1: Types of Structures."

Classifying Structures

Sponges are great when it comes to washing a car (or anything else for that matter). Sponges are used because they hold water very well. They make it easy to spread sudsy water over the surface you are washing. The sponges you use are likely manufactured. Did you know that there are natural sponges, too? If you were in the West Indies, you might be able to go diving for sponges. They are the remains of aquatic animals. More precisely, they are the skeletons of these animals. Manufactured sponges are human-made and designed to have a structure similar to natural sponges.

This is one way to group structures. Are they natural or are they human-made (manufactured)? This grouping is based on the origin of the structure, not on the structure itself.

Turn to pages 270 to 272 of the textbook and read "Classifying Structures." You will read about natural and manufactured structures.

1. Define the following terms:

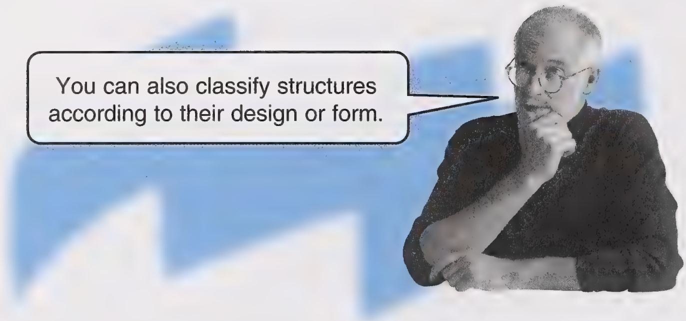
   - *structure*
   - *load*
   - *natural structure*
   - *manufactured structure*

2. Refer to the structures pictured on page 271.

   a. Which natural structure has an exterior most like a porcupine?

   b. Which manufactured structure is based on a sphere?

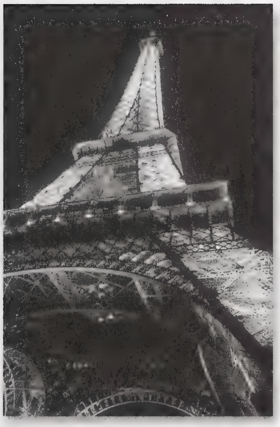
Compare your responses with those in the Appendix, page 61.



There are many examples of structures that are truly massive. Look at the pictures here. What do you see?

The photos show the sphinx from ancient Egypt, a nearly 2000-year-old pyramid in Mexico, and a modern concrete dam.

Find out more about the type of structure these examples represent. Turn to pages 272 and 273 of the textbook and read "Mass Structures."



The pictures here show several frame structures. Was your home framed when it was built? Most of the buildings in Alberta towns and cities have been. The house under construction shows the framing inside. The Eiffel Tower shows how effective metal framing can be. The towers holding power lines show their frames very clearly. In fact, that's all there is.

Find out more about the type of structure these photos represent. Turn to pages 274 and 275 of the textbook and read "Frame Structures."

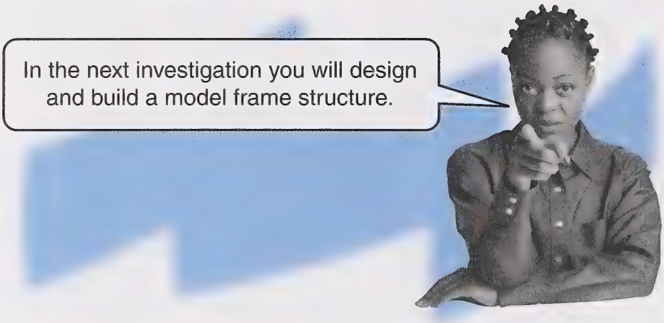
In the next activity you will compare a manufactured frame structure to a natural frame structure.

Find Out Activity **Picture a Frame**

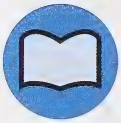
Read the entire activity on page 275 of the textbook.

3. Carry out steps 1 to 3 of the procedure, and answer the questions posed. For step 1, you may trace the textbook diagrams.

Check your responses with your teacher or home instructor.



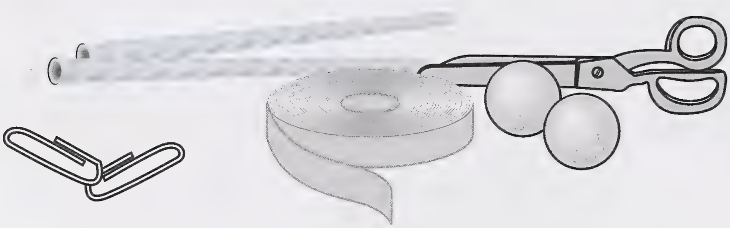
Investigation 4-A Golf Ball Bridge



Read the entire investigation on pages 276 and 277 of the textbook.

Note: You will need a friend or family member to help with brainstorming and planning your design. Have your design checked by your teacher or home instructor before you proceed with the building phase of this activity.

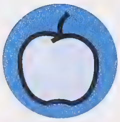
Carry out the steps of "Plan and Construct." If you are having trouble coming up with any design ideas, look at the shapes within the structures in Figures 4.6 (page 274), 4.10 (page 280), 4.11 (page 280), and 4.12 (page 282). Also, refer to the photos on pages 276 and 277.



4. Answer the following questions on page 277 of the textbook.

   a. questions 1, 2, and 3 of "Evaluate"

   b. question 5 of "Extend Your Knowledge"



Check your responses with your teacher or home instructor.

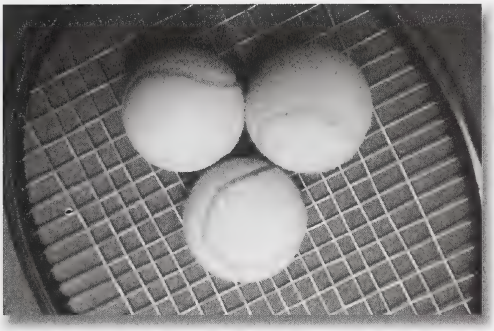
end of investigation

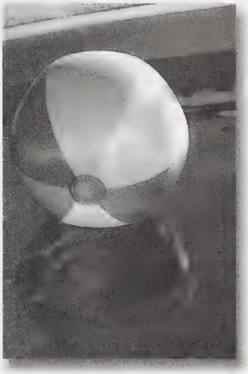
Going Further

Refer to “Internet Connect” on page 278 of the textbook. Find out who builds concrete canoes and why.

Do you like taking toys apart to see how they were put together. Maybe you would like civil engineering. Marie-Anne Erki does. Read “Across Canada” on page 279 of the textbook to find out more about her work.

Sometimes the outside is all there is to a structure. Take a look at these pictures.





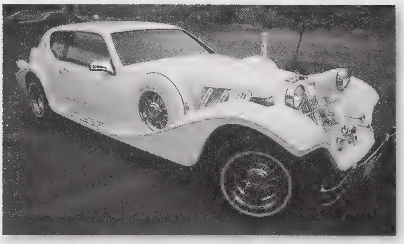
[1]

It’s easy to see that the beach ball is just a shell. It doesn’t need any other parts to make it functional. The same is true for the other balls. The dome on the Alberta Legislature is a similar structure.

Find out more about the type of structure these pictures represent. Turn to pages 278 and 279 of the textbook and read “Shell Structures.”

[1] Photo provided courtesy of Speaker of the Legislative Assembly of Alberta.

Structures don't have to fit one type only. Look at these pictures.



You should be able to recognize shells and frames in each picture. In addition the car's engine might be considered a mass structure, but then you can't see it. These objects seem to mix the other types together to carry out a certain function.

Find out more about this type of structure, turn to page 280 of the textbook and read "Mix and Match."

5. What natural structure is similar to a fishing net?

6. List four classes of structures based on design. Give one example of each.

7. Suggest the purpose of the clay core; the sand, cement, and clay block; and the waterproof grout curtain at the centre of the dam in Figure 4.5 on page 273.

8. Describe how a frame structure differs from a mass structure.

9. Provide one advantage a frame structure has over a mass structure.

10. What is one advantage of the mix and match structure design?

Compare your responses with those in the Appendix, page 61.

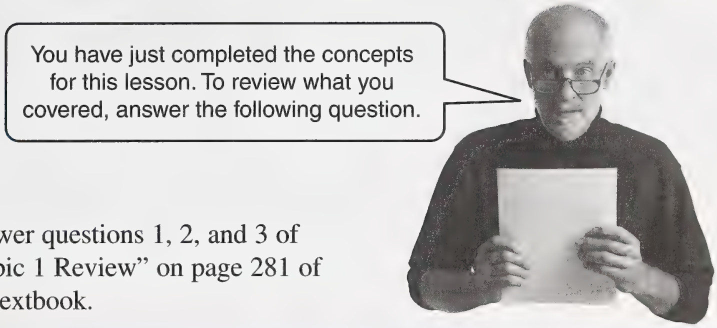
Going Further

11. An average bedroom has a volume of approximately 21 m^3 (cubic metres). How many bedrooms full of material would it take to equal the amount of material used to construct the dam described in "Did You Know?" on page 272 of the textbook.

Compare your response with the one in the Appendix, page 62.

Going Further

Designers need to be original thinkers. Do questions 1 and 2 of "Stretch Your Mind" on page 281 of the textbook.



12. Answer questions 1, 2, and 3 of "Topic 1 Review" on page 281 of the textbook.

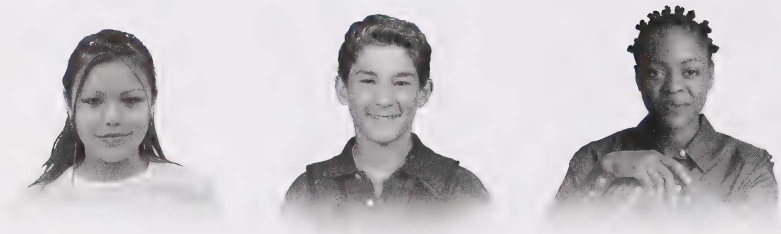
Compare your responses with those in the Appendix, page 62.

Looking Back

In this lesson you classified structures according to their origin. Were they natural or manufactured? You also classified them according to their design—mass, frame, shell, or mix and match.

Turn to pages 1 and 2 of Assignment Booklet 4A and answer questions 1 and 2.

Lesson 2: Describing Structures



Tara: Hi Austin. What's new?

Austin: A lot! My parents told me today that I don't have to share a room with my little brother anymore—they are going to build me my own bedroom.

Tara: That's super!

Austin: You can say that again! Mom and Dad said they have saved enough money to add on to the house. They even want me to come up with some sort of design.

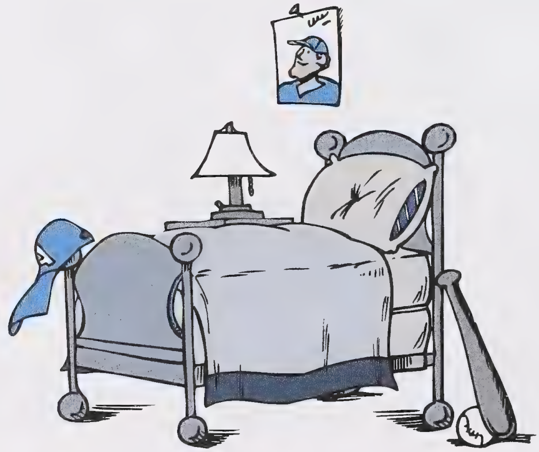
Tara: So, how are you going to set it up?

Austin: I don't know. All I know is that I have a certain amount of space and that I have to be within a certain budget. Ms. Burton, what do I need to think about when it comes to designing a bedroom?

Ms. Burton: Well, other than for shelter, your bedroom should be a comfortable place to sleep. Then you must ask youself questions like, "How much closet space will I need?" and "Do I want my bedroom to be a good place to study, do homework, and retreat to?"

Austin: Thanks, Ms. Burton. You've given me a good start. Tara, do you want to help me design my new bedroom?

Tara: Sure. Let's go.



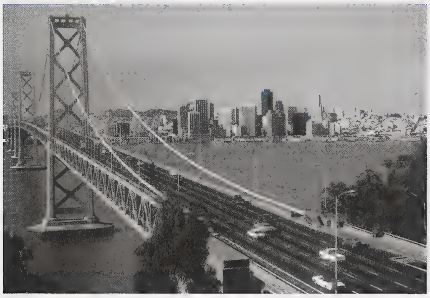
Austin must focus strongly on the intended purposes of his bedroom during the design stage. Otherwise, he could be stuck with a structure that would not meet his needs.

> To start the design of any structure, you need to have a clear idea of its purposes. You also have to think about appearance, safety, and construction materials. That's what architects and engineers do when they design structures.

Turn to page 282 of the textbook and read the introductory paragraphs of "Topic 2: Describing Structures." Find out what the designer of the Lethbridge trestle bridge could tell you about planning a bridge.

Function, Aesthetics, and Safety

Function



When people build things, they usually have a reason. These bridges look like they were built to let cars cross water. Other bridges are built for trains. What more do bridges and other structures have to do?

Turn to pages 283 and 284 of the textbook and read "Function."

1. What is one of the very important functions of a structure, such as bridge or a building?

2. Do "Word Connect" on page 283 of the textbook.

3. Read "Did You Know?" on page 284 of the textbook. Answer the question posed.

Compare your responses with those in the Appendix, page 62.

Aesthetics

Aesthetics—a pleasing appearance—is also important for structures. This is particularly true for clothing, jewellery, and monuments. But it is also true for bridges, houses, and airplanes.

Think of flowers, butterflies, and ladybugs. Do you think aesthetics are important in nature as well?

Turn to page 284 of the textbook and read "Aesthetics."

4. List some factors that affect the aesthetics of a structure.

Compare your response with the one in the Appendix, page 62.

Safety

Would you like to ride in a car that was designed to be cheap? Would you rather ride in one designed to be safe? What about bridges? Would you feel comfortable crossing a bridge where you know corners have been cut? Can you get both? Can you get a product that is both safe and less costly?

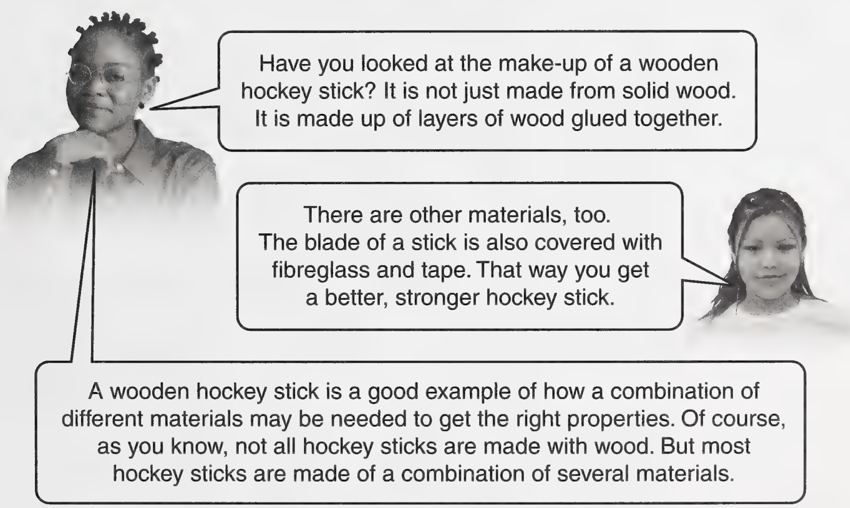
Turn to page 285 of the textbook and read "Designing for Safety" and "Balancing Safety with Cost."

5. What is meant by "margin of safety" in relation to structural design?

Compare your response with the one in the Appendix, page 62.

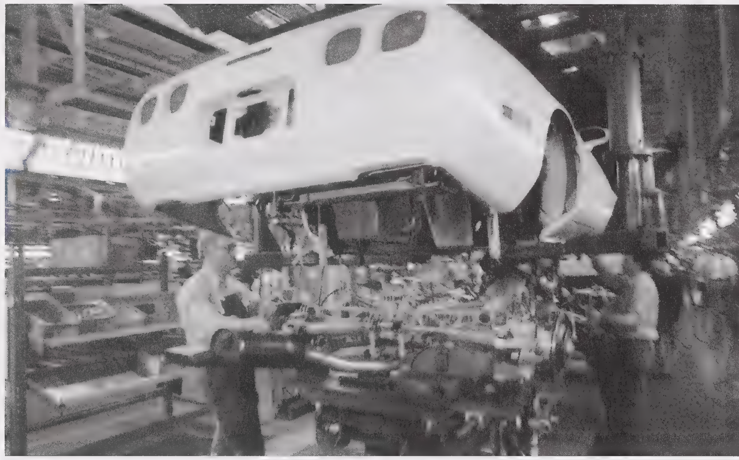
Turn to pages 2 and 3 of Assignment Booklet 4A and answer questions 3 and 4.

Combining and Choosing Materials



One type of material by itself, such as wood, may not have the needed properties. The way materials are combined is very important. The combination of materials affects the characteristics of a hockey stick or any other structure.

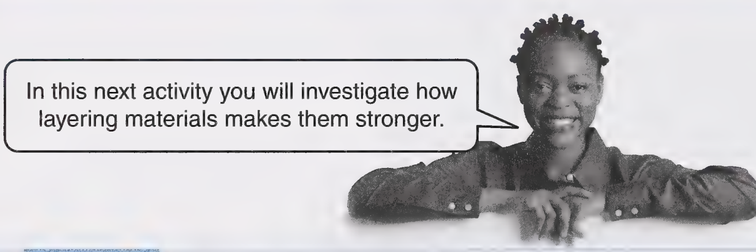
Turn to pages 286 and 287 of the textbook and read "Materials." Find out ways materials are combined to meet the design specifications of structures.



6. Define *composite material* and *laminated material*. Give an example of each.

7. How does the Karmann company produce a metal foam "sandwich" for car body panels. What advantage does this sandwich have over a single layer of the same material?

Compare your responses with those in the Appendix, page 63.



Find Out Activity Sneezeproof Strength

Read the entire activity on pages 287 of the textbook. Then follow the steps of the procedure. **Note:** You will need at least two different brands of facial tissues and a magnifying glass for step 1.

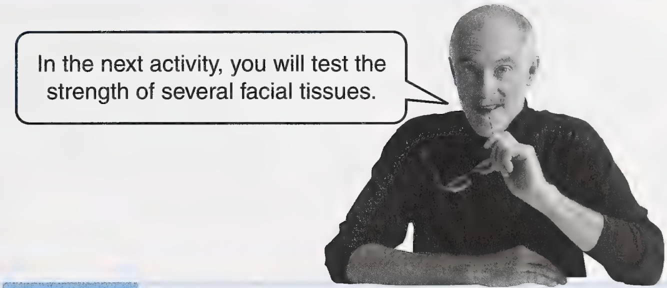
8. Answer questions 1, 2, and 3 of "What Did You Find Out?"

Check your responses with your teacher or home instructor.

Turn to pages 288 and 289 of the textbook and read "Choosing Materials." Choosing involves additional considerations that go beyond those related to design specifications of structures.

9. List four characteristics designers consider when selecting materials for a structure.

Compare your response with the one in the Appendix, page 63.



Find Out Activity Tough Tissue Test

Read the entire activity on page 289 of the textbook. Then follow the steps of the procedure. **Note:** You will need to get at least two samples of several different brands of facial tissues for this activity. You will also need a partner.

10. Answer the following on page 289 of the textbook.

    a. questions 1 to 4 of "What Did You Find Out?"

    b. question 5 of "Extension"

Check your responses with your teacher or home instructor.

Joints

Have you ever sat down on a chair and found that it wobbled? Most likely some of the glued joints had loosened. Very few structures—objects with a definite size and shape performing a specific function—consist of one single piece of material. How these pieces are joined is important. It affects the strength, stability, and performance of any structure.

Examine the room you are in for objects that qualify as a structure. How are the pieces joined? Did the designer decide to use glue, screws, Velcro™, hinges, or other options to hold the pieces together?

Choosing the method of joining parts of a structure is a critical design decision. Turn to pages 290 to 293 of the textbook and read "Joints." You will find there are many ways to put parts of a structure together.

11. Name the two major categories of joints found in structures.

12. You do not have to look far to find joints in structures. Study Figure 4.22 on page 290 and answer the question posed in the caption.

13. Name four types of fasteners used in joining parts of a structure.

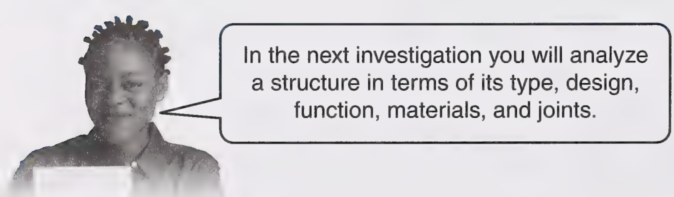
14. Two categories of rigid joints are interlocking shapes and ties. How are these two classes different? Provide an example of each.

15. Explain how adhesives join two pieces of material.

16. Describe the difference between welding and soldering.

Compare your responses with those in the Appendix, page 63.

Turn to pages 3 and 4 of Assignment Booklet 4A and answer questions 5 and 6.



Investigation 4-B Traditional Structures

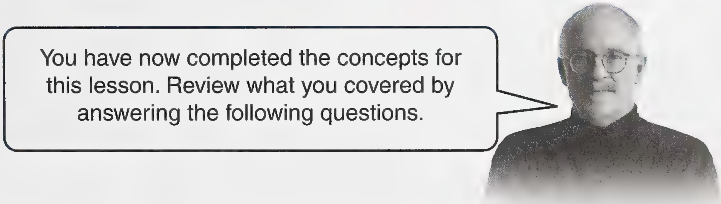
Turn to pages 294 and 295 of the textbook. Read the entire investigation. Then carry out the steps of the procedure.

Note: This investigation is designed as a group activity. However, if you select a simple structure with few parts (like an igloo), you can complete the investigation on your own.

17. Answer questions 1.a, 1.b., 1.c., 1.d., 1.f., and 3 of "Analyze" on page 295 of the textbook.

Check your responses with your teacher or home instructor.

end of investigation



18. Answer questions 1 to 4 of "Topic 2 Review" on page 296 of the textbook.

Compare your responses with those in the Appendix, pages 63 and 64.

Looking Back

In this lesson you identified the characteristics used to describe structures—structure type, function, safety, materials, joints, and aesthetics. You then evaluated structures based on these characteristics.

Section 1 Review

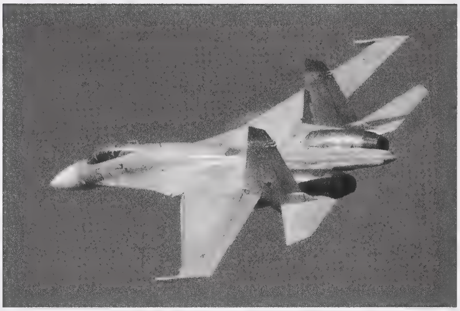
It's time to review the concepts covered in this section. Do the following "Wrap-up: Topics 1–2" questions on page 297 of the textbook.

1. Answer questions 1, 2, and 3 of "Reviewing Key Terms."
2. Answer questions 4 to 8 of "Understanding Key Concepts."

Compare your responses with those in the Appendix, pages 65 and 66.

Conclusion

In this section you classified and described structures. You studied how the design of structures and their functions are related. You then examined the role of materials, joints, and fasteners in structures.



The next time you the see the wings of an airplane, you will be aware that they function like those of a gull. Their common function leads both types of wings to have similar surface curvature. Whether natural or human-made, common purposes often lead to similar design.

Turn to pages 4 and 5 of Assignment Booklet 4A and answer questions 7, 8, and 9.

Section 2

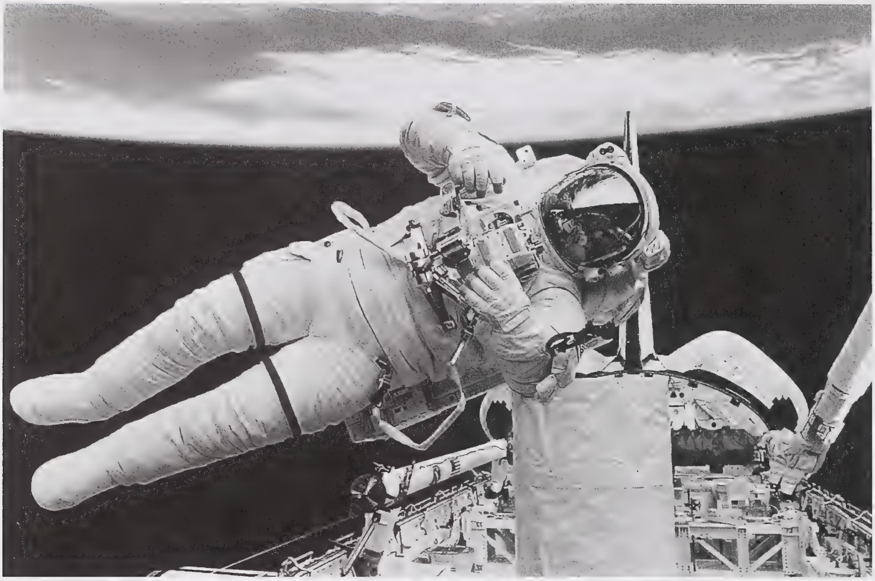
Explaining Structural Strength

Have you ever seen people sit in a lawn chair and rip through the material? There they were awkwardly held up in the frame of the chair. The chair failed but, besides a bit of hassle, there were no serious consequences. Now imagine the failure of a heavy-duty crane, for example—one that loads and unloads containers on and off ships. A failure like this would likely result in dropping a cargo container. There would be damage to the container and its contents. There might even be injury or death among nearby workers.

This kind of accident can be prevented. These structures' designs must make them stable and able to resist the forces applied to them. Designing fail-safe structures uses the concepts of force and weight.

In this section you will investigate the concepts of mass and weight. You will define the term *force*. You will identify and classify external and internal forces that affect structures and materials. You will also examine how these forces can cause structural failure.

Lesson 1: Mass and Forces



Astronaut in Shuttle Bay

Is the astronaut in the picture weightless? Many people would say so. It is a very commonly used, but inaccurate, description. After all, it is the force of gravity that keeps the astronaut (and the shuttle) in orbit around Earth.

The expression, "You're weightless in space" draws attention to the concepts of mass and weight. It shows the confusion that exists about these concepts. Because scales are marked in kilograms and you use a scale to check your "weight," it is very easy to be confused by these concepts. However, in science, it is important to have a clear understanding of what mass and weight describe.

In this lesson you will explore the concepts of mass and weight. You will also examine the differences between them.

Earlier in this module you looked at mass structures. They were built of large amounts of material. To see why certain types of structures are built as they are, there are some precise terms you need to be familiar with. Turn to page 298 of the textbook and read the first two paragraphs of "Topic 3: Mass and Forces."

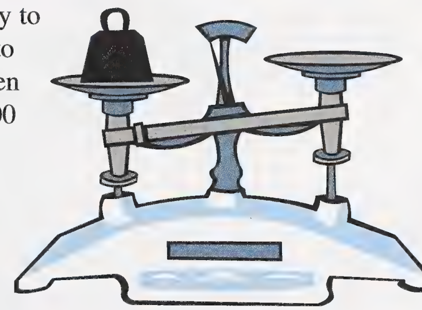
Now, you are ready to look at these ideas more closely. Turn to pages 298 and 299 of the textbook and read "Mass." It will give you an idea of how a physicist thinks of mass.

1. Define the term *mass*.

2. What is the base unit of mass in the SI system?

Compare your responses with those in the Appendix, page 67.

In your reading about mass, do you recall a way to compare masses? It stated that gravity is used to compare masses. Gravity is a force that has been studied for centuries. Turn to pages 299 and 300 of the textbook and read "Forces and Weight."



3. What is the standard SI unit of force?

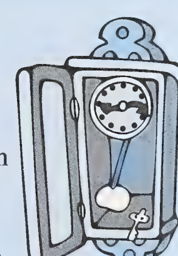
4. How does a balance measure mass?

5. How do you completely describe a force?

Compare your responses with those in the Appendix, page 67.

In common language, weight and mass are used interchangeably. Since Earth's gravity is pretty much the same everywhere, this works fairly well. Science, however, requires that they be thought of differently. Here's a little historical story that shows why this is so:

> In earlier times, pendulums were used to regulate clocks. Pendulums rely on gravity to keep their period of swing constant. Sir Isaac Newton (1642–1727) was a great English scientist. (He is honoured in the SI system by having his name used for the unit of force.) His writings show that he knew that the force of gravity changed from place to place on Earth. Newton saw this in the operation of pendulum clocks. Clocks that were accurate in England ran slower when they were moved closer to the equator. For everyday life, gravity on Earth is close enough to constant. But in science, close is often not good enough.



mass: the quantity of matter in an object

weight: the force of gravity exerted on a mass

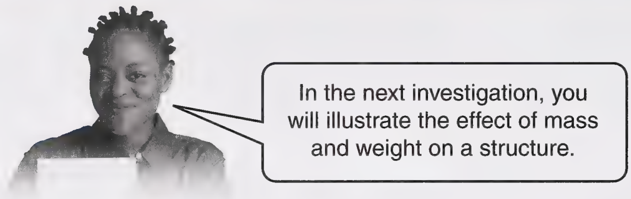
Turn to pages 300 and 301 of the textbook and read "Weight." You will find out more of the story about **mass** and **weight**.

6. According to Isaac Newton, a force exists between any two objects in the universe. Why do you not notice this force when you pass someone in the hallway?

7. What is the weight of a 1-kg mass on Earth?

8. Reread the four sentences (bulleted items) to the left of Figure 4.33 on page 301 of the textbook. State whether the terms and units of mass and weight are used correctly.

Compare your responses with those in the Appendix, page 67.



Investigation Strong to the Last Straw

Try to get a friend or family member to help with planning and carrying out this activity. You should be able to find the required materials in your home.

Challenge

Use as few materials as possible to construct a straw structure that will support 125 mL (0.5 cups) of sand.

Materials

- 10 straws
- connectors
  - 30 cm of tape
  - 10 paper clips or pins
- 250-mL plastic cup or Styrofoam® cup (small)
- 125 mL of sand

specifications: a set of standards or written instructions that define the requirements of a plan or structure

Specifications

A: The structure must be free-standing and at least 5 cm tall.
B: The structure must support 125 mL of sand for at least 30 s.
C: Only the listed materials may be used during construction.
D: The structure must be designed and built within 20 min.

Evaluate

9. Did your structure meet its specified objective?

10. How did the weight of the sand affect the structure?

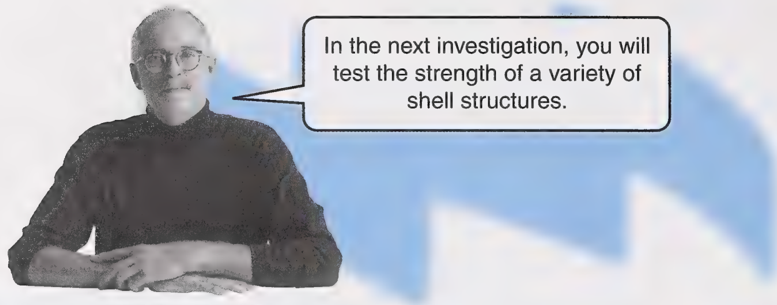
Compare your responses with those in the Appendix, page 67.

end of investigation

Going Further

Refer to "Find Out Activity: How Forceful!" on page 301 of the textbook. This activity illustrates the effect of gravity on two masses or objects.

Follow the procedure carefully. Then answer the questions posed in "What Did You Find Out?"



force meter: *a device used to measure force*

A spring scale is an example of a force meter.

Investigation 4-C Crush It!

Read the entire investigation on pages 302 and 303 of the textbook.

Carry out the steps of the procedure. Select four different shell structures from the suggested list under "Materials" to test. **Pay special attention to the safety precautions mentioned.**

11. Answer the following on page 303 of the textbook.

    a. questions 1, 2, and 3 of "Analyze"

    b. questions 4, 5, and 6 of "Conclude and Apply"

Check your responses with your teacher or home instructor.

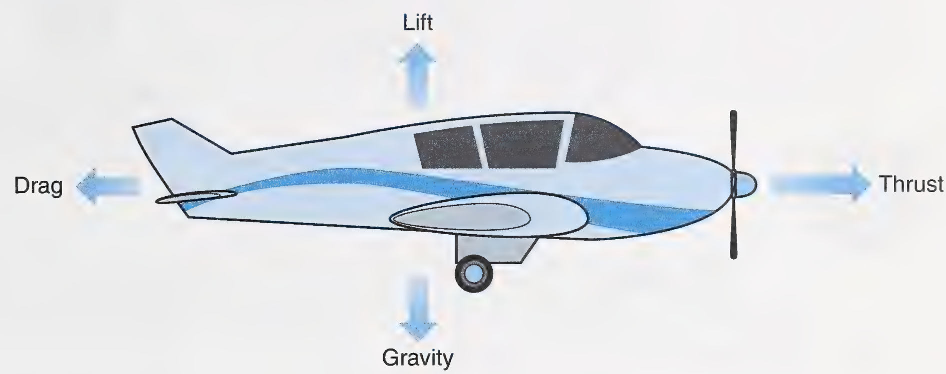
end of investigation

Going Further

12. Do "Math Connect" on page 303 of the textbook.

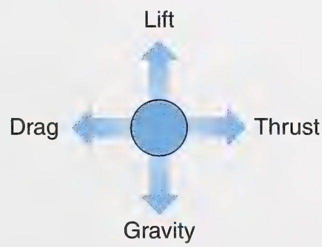
Compare your response with the one in the Appendix, page 67.

Representing Forces Visually



This diagram shows some of the forces acting on an airplane while in flight. Diagrams are very useful. They help you see what is going on in complex situations. However, drawing an object, like an airplane, can be tedious and hard to do, especially if you can't draw very well.

To show the forces on an object, like those on the airplane, you can draw a simplified diagram. Use a circle (or dot) to represent the airplane. This is called a force diagram. Scientists and engineers often use force diagrams to illustrate how forces act on objects and systems.



Turn to page 304 of the textbook and read "Picturing Forces." You will see how force diagrams are used.

13. How does a force diagram illustrate the following?

    a. force

    b. the object

14. Draw a force diagram showing the forces acting on your book bag as you hold it in your hand.

Compare your responses with those in the Appendix, pages 67 and 68.

You have now completed the concepts for this lesson. To review these concepts, do the following questions.

15. Answer questions 1 to 4 of "Topic 3 Review" on page 304 of the textbook.

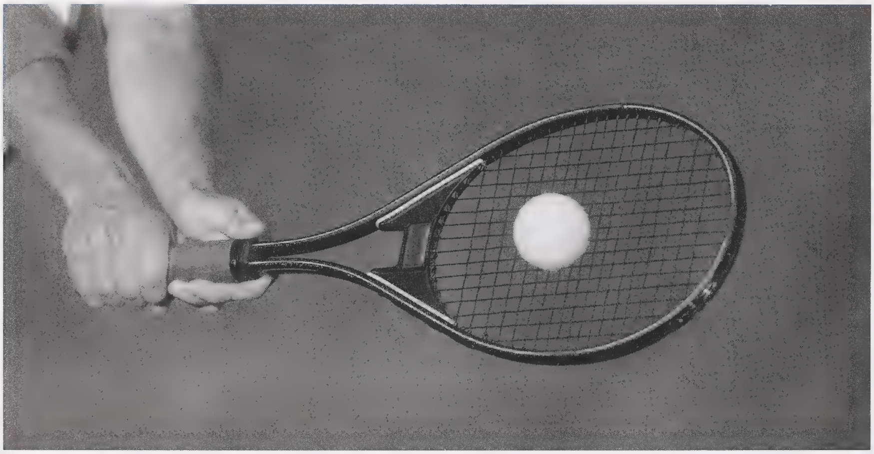
Compare your responses with those in the Appendix, page 68.

Looking Back

In this lesson you investigated the concepts of mass and weight. You also identified the units and instruments used to measure mass and weight.

Turn to page 5 of Assignment Booklet 4A and answer questions 1 and 2.

Lesson 2: Forces, Loads, and Stresses



Have you ever seen a tennis ball split open? How did this happen? Did the force of the racquet split the ball? Was it run over by a big truck? What happened inside the material for the ball to split?

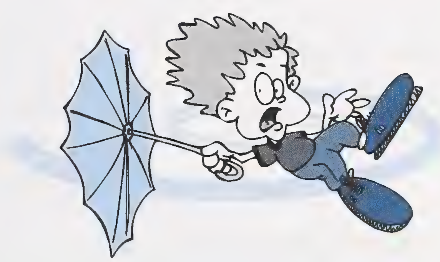
In previous lessons you looked at forces. You saw that an external force acts on an object in a particular direction. Such a push or pull can change the object's speed or direction of motion. The change of a ball's speed or direction of motion is certainly clear when you hit the ball with a racquet. But an external force can also change the shape or size of an object or even break it.

The design of a structure must consider external forces. The structure must be able to withstand the forces that are expected to occur. What happens when a structure is hit by a very large external force? Very large internal forces develop and something may break.

Read the introductory paragraphs of "Topic 4: Forces, Loads, and Stresses" on page 305 of the textbook. It gives a description of external and internal forces and how they affect objects.

1. Define *external force* and *internal force*.

Compare your response with the one in the Appendix, page 68.



Have you ever had to climb a hill? How about walking home in a big windstorm? Have you seen a water balloon hit the ground? If you have experienced any of these, you know something about external forces. Now it's time to get an even better idea about them. Turn to page 306 of the textbook and read "External Forces."

2. Define *dead load* and *live load*. Give an example of each.

Compare your response with the one in the Appendix, page 68.

As you saw in the last reading in the textbook, external forces can cause internal forces. You experience these every day. Is it easy to jump up in the gym and touch the basketball net? Think of the forces your muscles are putting on your bones when you try. Do you chew your food? Think about the forces the roots of your teeth have to contend with.

To find out more about internal forces, turn to pages 307 to 309 of the textbook and read "Internal Forces."

3. List and describe four types of internal forces.

4. Do "Pause and Reflect" on page 307 of the textbook.

Compare your responses with those in the Appendix, page 69.

You started this module discussing the particles that make up objects. How these particles act together explains a lot about the properties of the object. Turn to page 314 of the textbook and read "Resisting Stress—The Inside View."

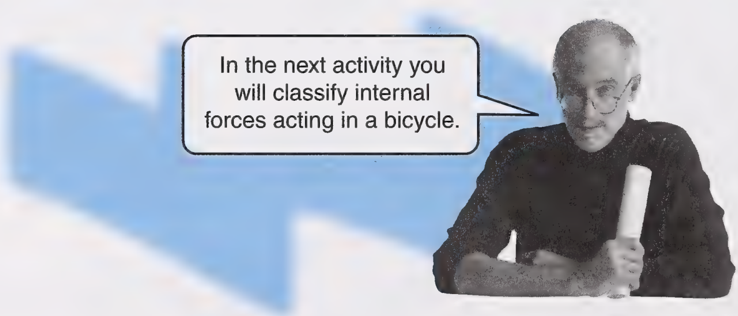
5. Give reasons for the following.

   a. Steel has a high tensile strength.

   b. Graphite is an excellent dry lubricant.

   c. Rubber has a high torsion strength.

Compare your responses with those in the Appendix, page 69.



Find Out Activity Bend That Bike!

Read the entire activity on page 308 of the textbook. Then follow the steps of the procedure.

6. Construct and complete the data table described in the procedure.

Compare your response with the one in the Appendix, page 69.

In the next investigation, you will examine the effects of forces acting on a variety of different structures.

Investigation 4-D Examining Forces

Read the entire investigation on pages 310 to 313 of the textbook. This activity has four separate parts. Scan each part to get the gist of it. Then complete all four parts of the investigation.

The following modifications may help you:

Part 2: Omit step 5 of the procedure if you are unable to obtain the pieces of polystyrene (a very dense insulating material).

Part 3: Use a measuring cup graduated in millilitres (mL) instead of a graduated cylinder.

Part 4: You may get help from a friend or family member. **Caution: Keep your feet out of the path of falling objects.**

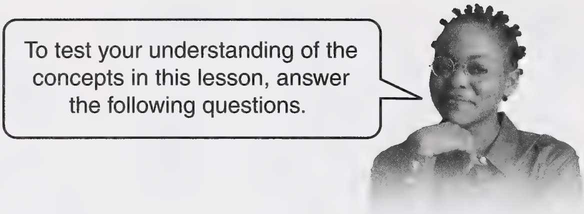
7. Answer the following on page 313 of the textbook.

   a. question 1 of "Analyze"

   b. questions 3 and 4 of "Conclude and Apply"

Check your responses with your teacher or home instructor.

end of investigation

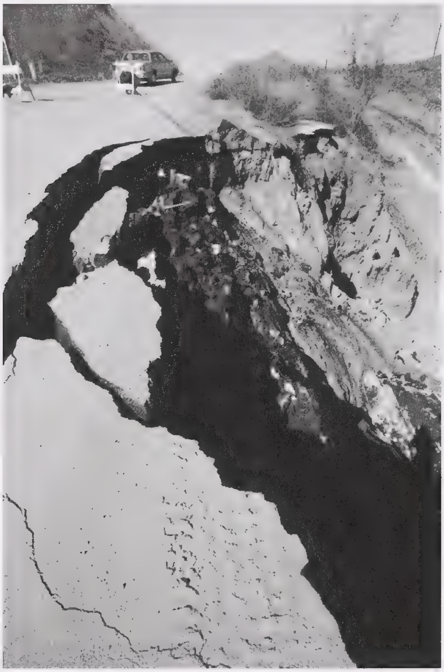


8. Answer questions 1 to 5 of "Topic 4 Review" on page 314 of the textbook.

Compare your responses with those in the Appendix, page 70.

Looking Back

In this lesson you identified and classified external and internal forces. You also studied the effect they have on structures.



Turn to pages 6 to 8 of Assignment Booklet 4A and answer questions 3 to 10.

Lesson 3: How Structures Fail

All structures, and the materials they are composed of, are subjected to external and internal forces. When such forces are too large, the structure deforms or breaks. For example, a river bank may slump under its own weight. You usually think of such changes as the structure failing.

lever: a simple machine consisting of a rigid bar that is free to rotate around a fixed point; used to multiply force or motion (speed)

In this lesson you will study how materials fail. You will see how structural design can prevent failure. You will also examine how stress in materials is put to good use.

External forces acting on structures can be multiplied by the structure's shape. For example, they may act like a **lever**. Designers consider this. They strengthen the materials at critical points of the structure to prevent failure.

fulcrum: the rigid point of support about which a lever rotates

The textbook discusses structural failure—what causes it, how it can be prevented; and how, by design, material failure is put to good use. Turn to pages 315 to 317 of the textbook. Read "Levers Create Large Forces," "How Materials Fail," and "Making Use of Stress."

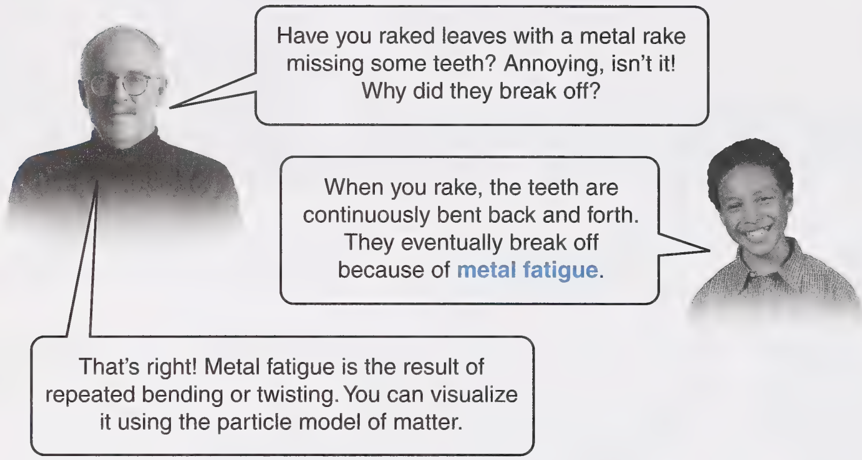
1. Where in a material is shear damage most likely to occur?
2. What type of force causes a structure to buckle?
3. Name two designs used to reinforce structures to prevent shear, bend, buckle, and twist failures.
4. Identify a useful application of the behaviour of materials under stress due to the following.

   a. buckle failure b. shear failure c. twist failure

Compare your responses with those in the Appendix, pages 70 and 71.

Going Further

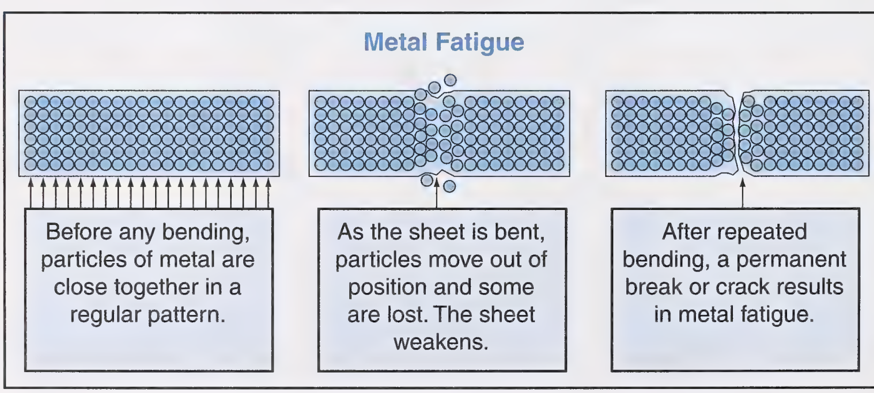
Want to know how buildings can be protected from earthquakes? Do "Internet Connect" on page 316 of the textbook. You will find that supporting buildings with giant shock absorbers is one way of protect buildings.

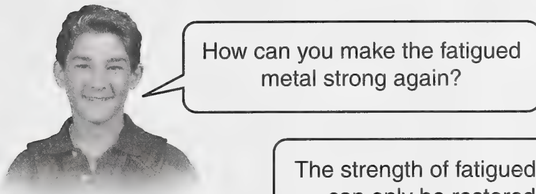


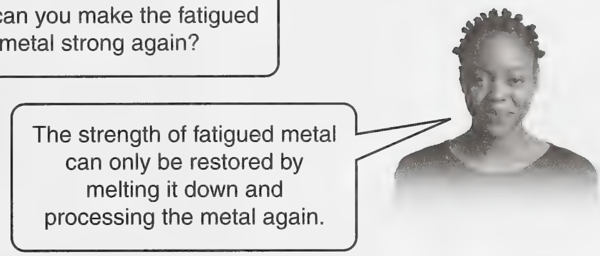
metal fatigue: a condition of weakness in metals or other solid substances caused by repeated changes in stress

Look at Figure 4.39A on page 314 of the textbook. It shows how metal particles are arranged and interact with one another. This arrangement can be distorted by bending or twisting. This can cause the attractive forces between the particles to weaken. Finally, even a slight stress can fracture the metal.

The effect is shown in the following diagram.







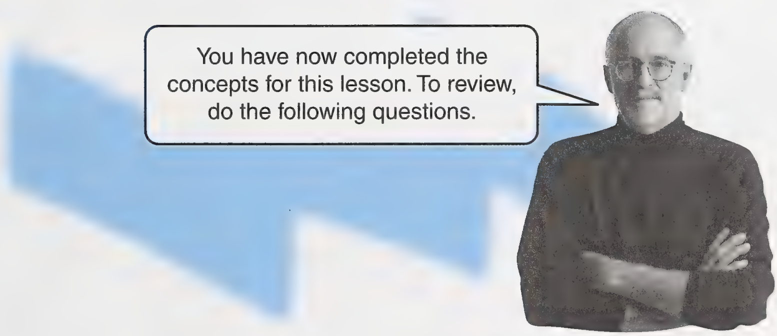
Turn to page 318 of the textbook and read "Metal Fatigue."

Going Further

Read "Find Out Activity: Bend and Break" on page 318 of the textbook. Then carry out the steps of the procedure.

5. Answer questions 1, 2, and 3 of "What Did You Find Out?"

Compare your response with the one in the Appendix, page 71.



6. Answer questions 1 to 5 of "Topic 5 Review" on page 319 of the textbook.

Compare your responses with those in the Appendix, pages 71 and 72.

Looking Back

In this lesson you studied how structures fail. You also found that some structures are designed to "fail" under certain conditions.

Section 2 Review

To review the concepts covered in this section, answer the following on page 320 of the textbook.

1. Answer question 1 of "Reviewing Key Terms."

2. Answer questions 2.a., 2.b., 2.c., and 5 of "Understanding Key Concepts."

Compare your responses with those in the Appendix, page 72.

Conclusion

In this section you studied the concepts of mass and weight and how they differ. You defined a force as a push or pull in a specific direction with a specific size. You found external and internal forces that structures contend with. You examined how these forces can lead to material failure.

You may know that some equipment obtains its power through a shaft connected to the power takeoff (PTO) of a tractor. The shaft carries turning motion from the tractor engine to the implement. (This saves having to put a separate engine on the implement.) Within the shaft is a shear bolt. It protects the tractor engine, shaft, and implement from abrupt overload. How? When the load is too great—maybe a rock gets into the implement—the shear bolt breaks. This interrupts the transmission of power. Damage to the more expensive parts of the machinery is prevented. By identifying internal and external forces, designers were able to come up with this clever way of protecting the machinery.

Turn to pages 8 and 9 of Assignment Booklet 4A and answer questions 11, 12, and 13.

Section 3

Making Structures Strong and Stable

Imagine having to design this bridge. If the bridge collapses, lives could be lost. Notice that it has only three supports across the river. Between the ends and the supports, the bridge must be strong enough to withstand its own weight, the force of wind, and the weight of the traffic going over it. To design a stable and strong bridge, you would have to design it with forces in mind. Designing for strength and stability is what this section is about.

In Section 2 you identified forces within and on structures. You saw how these forces related to the strength of structures. In this section you will apply what you learned about forces. You will learn to recognize designs that lead to strong and stable structures. You will also identify what design features can make structures break apart or tip over.

Lesson 1: Designing with Forces

Have you ever seen an old barn with a sagging roof? It's as if the years have taken their toll. The weight of the roof itself, plus the occasional heavy load of snow, causes the roof supports to bend.

The walls of a building must support the roof, and the roof must be able to withstand loads of snow. Understanding what forces act on a structure and the direction they act in helps engineers. They can then design structures that will successfully counteract these forces.

In this lesson you will consider the methods used to design strong structures.

Turn to pages 321 to 323 of the textbook. Read the introductory information of "Topic 6: Designing with Forces."

1. List three key methods used by designers to help structures withstand forces.

2. Provide one advantage and one disadvantage of a rectangular frame structure.

3. What is the advantage of using a triangular shape in a frame structure?

4. Why is it easier to bend a ruler on its flat side than on its edge?

5. Describe the shape and function of the keystone in an arch.

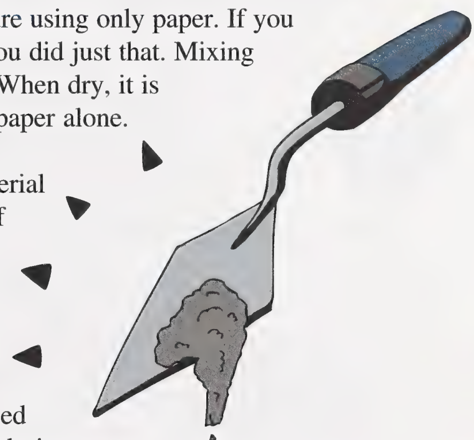
6. Define a *cantilever* and provide an example.

7. Why were structural shapes like the I-beam, L-beam, and box beams developed?

8. What is the function of a “flying buttress” in structural design?

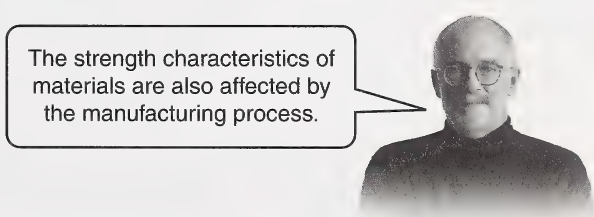
Compare your responses with those in the Appendix, page 73.

Strengthening Structures



It is very difficult to produce a rigid structure using only paper. If you ever crafted a shape using papier-mâché, you did just that. Mixing glue with paper yields a stronger material. When dry, it is capable of withstanding forces larger than paper alone.

As you found in the last section, every material has advantages and disadvantages. Some of these are based on the type of forces it can best support. Concrete, for example, has a high compressive strength but a very low tensile stress. Steel, on the other hand, has high tensile strength. The properties of concrete and steel are combined in reinforced concrete. Structural engineers can use it to design structures subjected to both compression and tension. No single material is able to withstand all types of forces without suffering some damage. It is important that designers carefully analyze every design they need to determine the kind of forces the structure must withstand.



Turn to page 324 of the textbook and read “Strengthening Structures.” You will see how a manufacturing process was used to eliminate shear fractures of railroad tracks.

The following investigation is a challenge. You will shape a simple material into models of strong, structural components.

Investigation 4-E The Paper Olympics

Refer to the investigation on page 325 of the textbook.

Use the design specifications to construct structural members. Test them according to the instructions given in "Plan and Construct."

Note: This investigation (as presented in the textbook) is a group activity. However, you can complete it on your own. You may want to talk to friends or your home instructor. Perhaps they will help you with the design, construction, and test phases. Study Figure 4.54 for a design inspiration. (This is the diagram that should have been given in step B of Design Specifications.) You may get some ideas to get you started.

9. Draw sketches of your designs in your notebook.

Check your responses with your teacher or home instructor.

end of investigation

Using Frictional Forces

Friction is a confusing phenomenon. You keep your bicycle chain clean and well lubricated to reduce friction; but you want maximum friction between your wheel rim and the brake pads for stopping. In curling, players reduce friction by sweeping the ice to make the rock run straighter; but they use friction between the ice and the stone to make it curl. Friction seems to be a "good news bad news" wonder in the physical world. By definition, friction opposes motion—it slows things down. But have you tried moving on a smooth, icy surface? So you need to minimize friction in some instances and maximize it in others.

For examples of how friction is used in structures, read "Using Frictional Forces" on pages 326 and 328 of the textbook.

10. Carefully study Figure 4.59 on page 326, and answer the questions posed.

11. Explain how the use of nails in wood structures is an example of the "good news bad news" aspect of friction.

12. What role does friction play when guitars, violins, and other string instruments go out of tune?

Compare your responses with those in the Appendix, page 73.

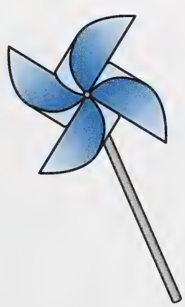
You can see friction as good or bad. In the next investigation you will make a model that shows the good side and the bad side of friction.

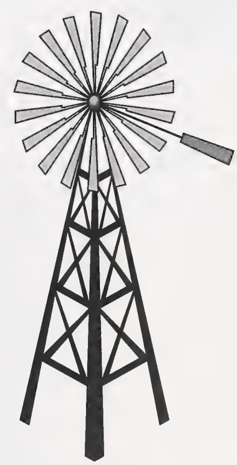
Investigation 4-F The Windproof Wonder

Read the entire investigation on page 327 of the textbook.

Follow the steps of "Plan and Construct." **Pay special attention to all the precaution mentioned.**

Tip: For design ideas, think of a paper windmill or the old-style water-pump windmills found on farms.



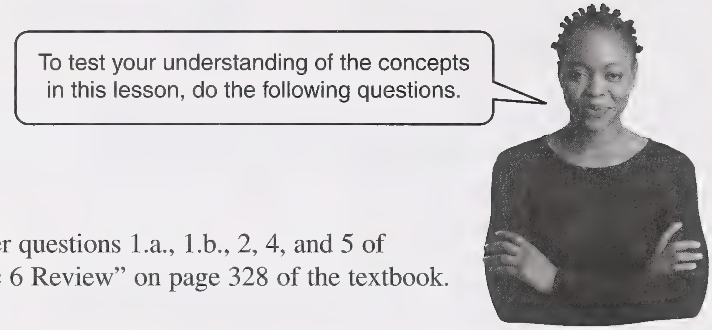


Note: For this investigation you should get a friend or two to help you. You may want to discuss your ideas with your teacher or home instructor.

13. Answer questions 1 to 4 of "Evaluate" on page 327 of the textbook.

Compare your responses with those in the Appendix, page 74.

end of investigation



14. Answer questions 1.a., 1.b., 2, 4, and 5 of "Topic 6 Review" on page 328 of the textbook.

Check your responses with your teacher or home instructor.

Looking Back

In this lesson you examined how a structure can be designed for strength. A strong structure can withstand both external and internal forces.

Turn to pages 1 and 2 of Assignment Booklet 4B and answer questions 1, 2, and 3.

Lesson 2: Stable Structures

How do the cranes in the photographs remain in an upright position—especially when loaded? The answer is in balanced forces. The counterweight of the crane balances the force of the load. The counterweight makes the crane stable.

In this lesson you will study structural stability. You will learn about design methods that increase structural stability.

Turn to page 329 of the textbook and read the opening paragraph of "Topic 7: Stable Structures." Study Figures 4.61 and 4.62 carefully.

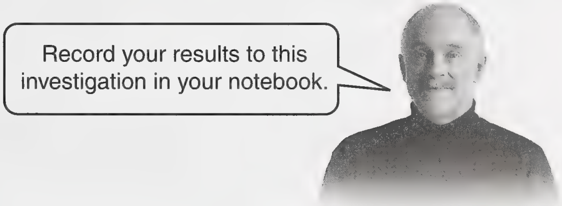
1. Answer the questions posed in Figures 4.61 and 4.62.

Compare your response with the one in the Appendix, page 75.

The following investigation will help you identify factors that affect balance and stability.

Investigation 4-G Tip It!

Read the entire investigation on page 330 of the textbook.



2. Answer questions 1, 2, and 3 of "Procedure" on page 330 of the textbook.

Compare your responses with those in the Appendix on page 75.

end of investigation

In Investigation 4-G you noted several "keys to stability." But you can get deeper insight into stability. Learn about the role of a point known as the centre of gravity. In the next activity, you will find the centre of gravity of an irregular shape.

Before you start the next activity, read "Balancing Act" on page 331 of the textbook.

Find Out Activity The Centre of Gravity

Read the entire activity on page 331 of the textbook.

Follow the steps of the Procedure. **Pay special attention to the caution in step 1.**

3. Answer questions 1 and 2 of "What Did You Find Out?"

Compare your responses with those in the Appendix on page 75.

In the last activity, you looked at the centre of gravity. It is the point at which all the parts of the object exactly balance each other. As far as stability is concerned, the centre of gravity is the point at which the force of gravity pulls down on an object.

Read the information on page 332 of the textbook. Study Figures 4.65A and 4.65B carefully.

4. Review your responses to question 1 at the beginning of this lesson. Do you want to modify your answers in light of what you found out in the last two activities?

Compare your response with the one in the Appendix, page 75.

Unbalanced Structures

What is the point where you balanced the cardboard in "Find Out Activity: The Centre of Gravity"? It is the centre of gravity of the cardboard shape. The force your finger applies at this point is balanced by the force of gravity acting on the cardboard. The centre of gravity of an object is a fixed point. It's the point where all the gravitational force on an object can be considered to act. A vertical line drawn downward from the centre of gravity points to the centre of Earth. Such a line is referred to as a **plumb line**.

plumb line: *a vertical line directed to the centre of gravity of Earth*

You can find the plumb line with a cord having a small lead weight at one end.

Knowing where the centre of gravity is can be very important. It and the base are related to the stability of the structure. Figures 4.64A and 4.65A show stable structures. The centre of gravity lies "inside" the base. The plumb line from the centre of gravity passes through the base. Figures 4.64B and 4.65B show unstable structures. The centre of gravity lies "outside" the base. The plumb line from the centre of gravity passes outside the base.

5. Answer the question posed in Figure 4.66 on page 333 of the textbook.

6. Do "Pause and Reflect" on page 333 of the textbook.

Compare your responses with those in the Appendix, pages 75 and 76.

Read the entire investigation on pages 334 and 335 of the textbook. Read the specifications very carefully. Then carry out the steps listed in "Plan and Construct."

This investigation is presented in the textbook as a group activity. Try and get help from a friend or family member.

7. Answer the following on pages 335 of the textbook.

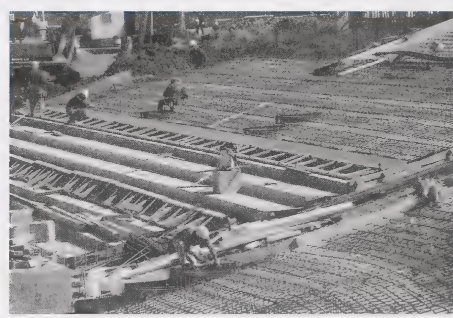
    a. questions 1, 2, and 3 of "Evaluate"

    b. question 4 of "Extend Your Skills"

Check your responses with your teacher or home instructor.

end of investigation

Making a Firm Foundation



Imagine building a large multi-story building. What do you have to prepare first? You need a stable and firm foundation. Such a foundation is critical for the stability of any structure.

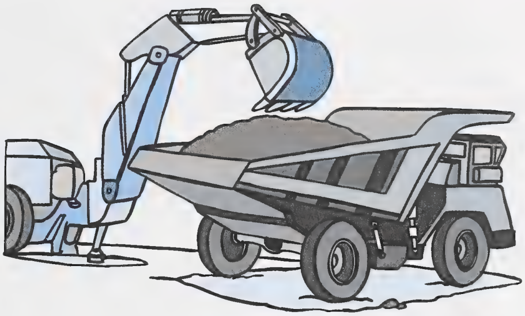
Turn to pages 336 and 337 of the textbook and read "Firm Foundation." Find out how designers and builders construct stable foundations.

8. What is the purpose of pilings in the foundation of a structure?

9. Identify two structures where packed gravel is used as the foundation.

10. Why is the footings wider than the foundation wall of a basement?

Compare your responses with those in the Appendix, page 76.

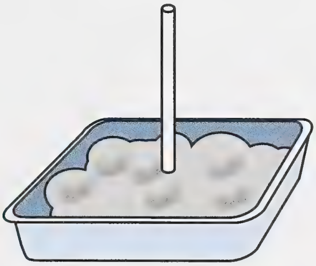


To make a firm foundation, you need to know what kind of soil you are building on. The following investigation works with the ideas behind soil testing. You will carry out a procedure similar to that used in soil testing at potential building sites.

Investigation 4-1 Sink the Stick

Refer to the investigation on pages 338 and 339 of the textbook.

Carry out the steps of the procedure. **Pay special attention to the safety precautions mentioned.**



11. Do "Math Connect" on page 338 of the textbook.

12. Answer the following on page 339 of the textbook.

    a. questions 1 to 6 of "Analyze"

    b. questions 7 to 12 of "Conclude and Apply"

Check your responses with your teacher or home instructor.

end of investigation

Going Further

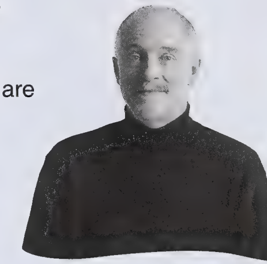
Mr. Casey: How does centre of gravity work with bicycles? Shouldn't you fall over very easily?

Mikaila: Yes, according to what I studied. When the support is narrow like a bicycle tire, things are unstable.

Mr. Casey: Now throw in the fact that you are moving. Wouldn't this make it even harder?

Mikaila: Maybe, but I don't fall over. What are we missing?

Mr. Casey: Spin stabilization is the missing factor. Spin stabilization also keeps a top upright. Just think how small the base of a top is.



Read "Rapid Rotation" on page 340 of the textbook for more on spin stabilization.

13. List three examples that use spin stabilization.

Compare your response with the one in the Appendix on page 76.

To review what you covered in this lesson, answer the following questions.

14. Answer questions 1, 2, and 3 of "Topic 7 Review" on page 340 of the textbook.

Compare your responses with those in the Appendix, pages 76 and 77.

Looking Back

In this lesson you looked at factors that affect the stability of a structure. You found several things that increased stability. They included a low centre of gravity, distributing the mass over a larger area, and a symmetric shape.

Section 3 Review

Now, it's time to review the concepts covered in this section. Turn to page 341 of the textbook and answer the following "Wrap-up: Topics 6–7" questions.

1. Answer question 1 of "Reviewing Key Terms."

2. Answer questions 3 to 7 of "Understanding Key Concepts."

Compare your responses with those in the Appendix, pages 77 and 78.

Conclusion

In this section you studied how to make a structure stable and prevent it from failing. You saw that using certain characteristics in the design helped. The centre of gravity, balancing forces, and load distribution are examples. You found that designers need to know the forces a structure will be subjected to. They use this knowledge to choose materials and shapes for a structure. Only then will the design safely fulfill its purpose.

From your work in this section, you found that there are many ways to design a structure for strength and stability. That is something bridge designers know, too. You could say that there are many ways to build a bridge.

Turn to pages 2 to 4 of Assignment Booklet 4B and answer questions 4 to 10.

Module Summary

In this module you classified and described structures according to their design and function. You studied the concepts of force, mass, and weight and saw their roles in the design, construction, and failure of structures. You then investigated how designers, engineers, and builders make functional, stable structures. You saw how they use their knowledge of materials and shape, the forces a structure must sustain, and the concept of balance. You saw how science and technology have improved designs today.

High-voltage power lines bring electricity from a power plant to a centre near your home. The towers holding up these power lines are key to keeping the lines safely above the ground. What did the designers have to understand? They needed to know about materials and shape and account for the forces applied by wind and the power lines. The result was skeletal, lightweight towers. They could be made with a minimal amount of materials and, yet, be strong and stable.

Turn to page 346 of the textbook and review the concepts listed under "Unit at a Glance." They give a quick review of what was covered in this module. Then answer the following "Unit 4 Review" questions on pages 346 to 349.

1. Answer questions 1, 4, 10, 11, 13, and 20 of "Understanding Key Concepts."

2. Answer questions 25 and 27 of "Developing Skills."

3. Answer questions 29 and 32 of "Problem Solving/Applying."

4. Answer questions 34, 36, and 38 of "Critical Thinking."

Compare your responses with those in the Appendix, pages 77 to 81.

Turn to pages 4 to 7 of Assignment Booklet 4B and complete the Final Module Assignment.

Appendix

Glossary

Suggested Answers

Image Credits

Glossary

aesthetics: the study of beauty in art and nature

cantilever: a horizontal board or other span supported only at one end by a very strong column

centre of gravity: the point at which all of the gravitational force may be considered to act on an object

composite material: material composed of several materials with different properties to fulfill a purpose

dead load: the weight of the structure upon itself; a continuously applied load

A dead load is constant in its position and magnitude (size), such as the weight of the structure and any permanently attached equipment.

external force: a force that acts on a structure from outside

force: a push or pull

force diagram: a drawing that uses arrows to represent the direction and size (strength) of one or more forces acting on an object

force meter: a device used to measure force

A spring scale is an example of a force meter.

fulcrum: the rigid point of support about which a lever rotates

gravitational force: the force exerted by gravity on an object (measured in newtons, N); the preferred scientific term for the term *weight*

internal force: a force that acts on a structure from within

kilogram (kg): an SI unit of mass

laminated material: material consisting of different layers of different materials

lever: a simple machine consisting of a rigid bar that is free to rotate around a fixed point; used to multiply force or motion (speed)

live load: a temporarily applied force acting on a structure

load: the weight carried by a structure

manufactured structure: an object or structure made by humans

mass: the quantity of matter in an object

metal fatigue: a weakening of metal due to internal stress

natural structure: an object or structure not made by humans

newton (N): the SI unit of force (weight)

plumb line: a line directed straight down from a point to the centre of Earth

specifications: a set of standards or written instructions that define the requirements of a plan or structure

structure: an object with a definite size and shape that serves a definite purpose or function

weight: the force of gravity exerted on a mass

Suggested Answers

The answers in this Appendix are an important part of this Science course. Read them carefully when checking your work. They provide additional information, examples, and clarification. They also give you a quick way to see if your answer is right. It is a good idea to copy the things you learn into your notebook. What you learn from the suggested answers is often used later in the module or course. Refer to them as needed.

Section 1: Lesson 1

1. A *structure* is an object with a definite size and shape that serves a definite purpose or function.

   Load is the weight carried or supported by a structure.

   A *natural structure* is an object or structure not made by humans.

   A *manufactured structure* is an object or structure made by humans.

2. a. The cactus has an exterior like a porcupine.

   b. The earthenware vases are based on a sphere.

3. Check your responses with your teacher or home instructor.

4. Check your responses with your teacher or home instructor.

5. A spider web is a natural structure similar to a fish net.

6. Four classes of structures based on their design are mass structures (e.g., a brick wall), frame structures (e.g., a house or office building), shell structures (e.g., an igloo or tin can), and a combination of two or more designs (e.g., a football helmet).

7. Because clay is denser than sand and does not allow water to pass through, the clay core is part of the waterproof barrier in the dam.

   The sand, cement, and clay block provides a solid, water-tight foundation for the clay core. Along with the clay core, the block helps anchor the dam structure.

   The waterproof grout curtain assures that water does not seep through the bottom of the dam and the soil below the dam.

8. A frame structure contains mostly empty space within, whereas a mass structure contains little or no empty space.

9. Frame structures require less material to build and are relatively easy to design and construct.

10. The mix and match structure design combines the advantages of two or more different designs.

11. Number of bedrooms $= \dfrac{\text{total amount of material}}{\text{volume of 1 bedroom}}$

$$= \frac{540 \text{ million m}^3}{21 \text{ m}^3\text{/bedroom}}$$

$$= 25.7 \text{ million bedrooms}$$

It would take about 25.7 million bedrooms full of material to equal the amount of material used to construct the dam.

12. **Textbook questions 1, 2, and 3 of "Topic 1 Review," p. 281**

1. a. frame b. shell c. mass d. shell

2. a. shell b. mass c. frame

3. a.

Object	Structure Type(s)
foam plastic wing	mass
balsa wood wing	frame
real airplane wing	frame and shell

Note: The metal skin of a real airplane wing is more than simply a covering to control air flow. The skin is a structural component that adds to the strength of the wing.

b. The foam object would be easier to build because you only need to shape a piece of foam.

Section 1: Lesson 2

1. One very important function of any structure is that it must support its own weight.

2. **Textbook question "Word Connect," p. 283**

The functions of a running shoe consist of the following:

- containing
- supporting
- sheltering
- holding
- lifting

3. **Textbook question "Did You Know?," p. 284**

The axis of symmetry runs from the head of the butterfly to the tail. When objects or organisms can be "cut" into two identical halves, they have bilateral symmetry.

4. The aesthetics of a structure are affected by the colour, shape, and texture of the materials used.

5. The margin of safety of a structure assures that it can support a greater load than is normally required.

6. *Composite material* is material that is composed of several materials with different properties to fulfill a specific purpose. Two examples are reinforced concrete and fibreglass.

   Laminated material is material that consists of different layers of different materials. Two examples are windshield safety glass and plywood.

7. Karmann produces the metal foam by forcing gases through hot, liquid metal. This makes bubbles that harden when they cool. The metal foam is covered with thin sheets of aluminum, making a "sandwich" that is ten times stiffer than steel and much lighter.

8. Check your responses with your teacher or home instructor.

9. Designers consider cost, appearance, environmental impact, and energy efficiency when selecting materials for a structure.

10. Check your responses with your teacher or home instructor.

11. Mobile joints and rigid joints are two major categories of joints used in structures.

12. Materials used for mobile joints need to be hard enough to resist wear and their surface must be smooth and rounded to reduce friction.

13. Nails, staples, bolts, screws, rivets, and dowels are fasteners used in joining parts of a structure.

14. Interlocking shapes are carefully shaped parts that hold pieces of a structure together. Examples include folded seams in sheet metal and cloth and dovetail joints in carpentry.

    Ties involve using a string or rope to fasten parts of a structure together. Shoelaces, drawstrings in jacket hoods, and sewing thread in clothing seams are examples.

15. Adhesives flow into tiny spaces of the surfaces they hold together while soft. When they harden, they lock the pieces together. Some adhesives actually dissolve a thin layer of each surface to be joined. These dissolved layers then harden, forming a solid joint.

16. Welding melts the surface of the pieces to be joined.

    Soldering surrounds the pieces to be joined with a different, molten material (solder) that locks the pieces together after it cools.

17. Check your responses with your teacher or home instructor.

18. **Textbook questions 1 to 4 of "Topic 2 Review," p. 296**

    1. Some possible functions the plastic sheeting could have are to

       - build a shelter
       - collect rainwater
       - build a solar still to produce drinking water
       - serve as a sail for a raft or boat
       - cover the frame of a boat (like a kayak)
       - make a net to catch fish or other wild animals

2. Answers will vary. Sample answers are given.

   a. wool sweaters and blankets, cotton clothing, rugs, and doormats

   b. plywood, counter tops, safety glass, posters, skis, skateboards, and snowboards

   c. bulletproof vests, car bodies, shafts of golf clubs, reinforced concrete, hockey sticks, snowboards, and surfboards

   d. stamps on a letter, patched tire tubes, and repaired cup handles

   e. clothing seams, parachute seams, and tent seams

   f. car frames, ship hulls, and airplane bodies

3. Answers will vary. Some questions you could ask are as follows:

   - Where is the building to be located?
   - How big does the building have to be?
   - How much do you want to spend on this building?
   - How many people do you expect to visit this building in a day?
   - Will the building have more than one floor?
   - How much parking do you want to provide?
   - How soon does the building have to be completed?

4. a. Your foot is used to support body weight, help move your body, kick, and grip the floor (or ground).

   b.

Material	Function	Property
bones	support weight	resist compression
tendons	move toes	resist tension well
muscles	provide pull	moves foot
skin	covers and protects	resist tension well

   c. Your foot is a frame structure with many mobile joints.

   d. The bones are tied to each other with ligaments. The muscles are tied to the bones with tendons. The human foot has 26 bones. The ligaments and tendons are strong cords that fasten the parts together.

Section 1 Review

1. **Textbook questions 1, 2, and 3 of "Reviewing Key Concepts," p. 297**

    1. Answers will vary. Sample pairs are given.

        - Umbrellas and mushrooms have similar shape. They have a similar function. The umbrella protects the person underneath from rain. The top of the mushroom protects the spore-bearing gills attached underneath from rain and sunlight.

        - Parachutes and dandelion seeds ("parachutes") have a similar function. They both slow down the fall of the person or seed in the air. Their structures, however, are different. On the top of the slender stem coming off the seed are a number of fine projections. They spread out like the ribs of an open umbrella.

        - Submarines and fish have similar shape. They are streamlined. Their shape makes their movement through water easier.

        - Airplanes and birds have similar wing and body shapes. Their wings provide lift to make flight possible. Also, their bodies are streamlined to reduce air resistance.

    2. Answers will vary. Sample answers are given.

        a. Examples of mass structures are as follows:

        - earthen dams
        - mountains
        - snow sculptures
        - stone, concrete, or brick wall
        - coral reefs

        b. Examples of frame structures are as follows:

        - steel bridges
        - electrical towers
        - skyscrapers
        - wooden decks
        - frame houses
        - tents
        - the human body

        c. Examples of shell structures are as follows:

        - bowls
        - bottles
        - pipes
        - the Taj Mahal
        - eggs
        - tin cans
        - igloos

    3. In a welded joint, the surface of the two pieces are joined together by melting them into one another. In an adhesive joint, the attraction between the adhesive and the surfaces holds the two pieces together.

2. **Textbook questions 4 to 8 of "Understanding Key Concepts," p. 297**

4. a. The juice is not a structure because it does not have a definite shape.

   b. The glass is a structure because it has a definite shape.

5. a. Glass is easy to shape, so containers can be any shape desired. Glass does not react with most substances, and it does not change the flavour of the beverage. Glass is easy to clean and can be sterilized, so the container can be reused. Glass can be transparent, so the buyer can see the product.

   b. Glass breaks easily, making the container potentially dangerous. Glass is relatively expensive to produce. If the container cannot be reused, it is not cost-effective. Also, glass is heavy and could increase transportation costs.

6. a. The main function of wooden shoes is to support and protect your feet.

   The main function of soft, leather moccasins is to protect your feet.

   The main function of sports sandals is to protect the soles of your feet and be comfortable in hot weather.

   The main function of downhill ski boots is to support and protect your feet. The rigid structure facilitates transmitting the action of your feet and legs to the skis.

   b. Wooden shoes are shell structures.

   Soft, leather moccasins are shell structures.

   Sports sandals are a combination of frame (top) and mass structures (sole).

   Downhill ski boots are shell structures.

   c. No fasteners are required on wooden shoes if they are carved out of a single piece of wood. If more than one piece of wood is used, they are glued together.

   Ties are used as fasteners on soft, leather moccasins.

   Adhesives and/or welded seams (sole), Velcro™, and/or buckles (straps) are used as fasteners on sports sandles.

   Adhesives, welded seams, rivets, and buckles are used as fasteners on downhill ski boots.

7. a. Whole reeds are best lined up and tied together to form a layer because they crack and lose their floatation when woven.

   b. Placing the layers at right angles to each other yields a stronger platform.

8. a. The holes the ties pass though weaken the material.

   b. Cooling a welding joint evenly is critical to its strength. Uneven cooling yields a weak joint. Also, heating the surfaces that are to be joined for too long makes a weak joint.

Section 2: Lesson 1

1. *Mass* is the amount of matter in a substance.
2. The base unit for mass in the SI system is the kilogram (kg).
3. The standard SI unit of force is the newton (N).
4. A balance compares the force of gravity acting on a mass with the pull of gravity on a standard mass.
5. A force is completely described by stating its magnitude (size) and the direction in which it acts.
6. The gravitational force Newton predicted to exist between any two objects is not noticed between ordinary objects. It only becomes significant when one or both objects are very large, like Earth for example.
7. The weight of a 1-kg mass on Earth is approximately 9.81 N (rounded to 10 N in the textbook).
8. In the first sentence, the term *mass* is used correctly. Although the spring in a spring scale responds to the force of gravity, the dial of the supermarket scale is calibrated in kilograms, allowing you to find the mass of the fruit. A balance scale would be the correct instrument to measure mass.

   In the second and fourth sentences, the term *weight* is used incorrectly. The kilogram (kg) is a unit of mass; weight is measured in newtons (N).

   In the third sentence, the term *mass* is used incorrectly. The mass of an object remains constant. Weight is dependent on gravity, so it changes as an object moves relative to the centre of Earth.
9. Answers will vary. The structure may have collapsed under the load or it may have supported the load.
10. Answers will vary. The weight of the sand may have caused the supports to bend.
11. Check your responses with your teacher or home instructor.
12. **Textbook question "Math Connect," p. 303**

    Answers will vary. Answers depend on cone strength and the individual's weight. A sample answer is given.

$$\begin{aligned}\text{Number of cones required to support weight} &= \frac{\text{your weight (in N)}}{\text{force (in N) supported per cone}}\\ &= \frac{500\ \text{N}}{2.5\ \text{N/cone}}\\ &= 200\ \text{cones}\end{aligned}$$

13. a. The direction and length of an arrow illustrates the direction and strength of a force in a force diagram.

    b. The object is illustrated by a circle (dot) or rectangle.

14. The arrows representing the force are opposite in direction and equal in length.

15. **Textbook questions 1 to 4 of "Topic 3 Review," p. 304**

1. a. To measure the weight of a pencil, you should use a spring scale or force meter calibrated in newtons.

   b. You should report the weight of the pencil in newtons (N).

2. To fully describe the force they applied, the direction of the force must be reported as well.

3. Answers will vary. Sample sentences are given.

   - My mass is 50 kg, and my weight is 490.5 N.
   - The mass of the 1.96-N banana is approximately 200 g.
   - Moving an object farther from Earth decreases its weight, but its mass remains the same.

4. a. 125 g = 0.125 kg

   b. $0.125 \text{ kg} \times 10 \text{ N/ kg} = 1.25 \text{ N}$

Note: 1 N/kg is the same as 1 m/s^2, since $1 \text{ N} = 1 \text{ kg} \bullet \text{m/s}^2$. Also, you might have got an answer of 1.23 N, which is based on $g = 9.81 \text{ m/s}^2$. This is more accurate.

Section 2: Lesson 2

1. An *external force* acts on a structure from outside.

   An *internal force* acts on a structure from within.

2. A *dead load* is the weight of the structure upon itself. The weight of a building is an example of a dead load.

   A *live load* is a force or forces that act in or on a structure that is not part of the structure. Wind whipping around a building or vehicles crossing a bridge are examples of live loads.

3. Four types of internal forces are as follows:

   - **tension forces:** forces that stretch a material by pulling its ends apart (For example, cables and ropes are usually subjected to tension forces.)

   - **compression forces:** forces that squeeze a material together (For example, your weight compresses the ground you stand on.

   - **shear forces:** forces that bend or tear a material by pressing different parts in opposite directions at the same time.

   - **torsion forces:** forces that twist a material by turning the ends in opposite directions.

4. **Textbook question "Pause and Reflect," p. 307**

   External forces are forces applied to a structure from outside. Internal forces are stresses acting within the material of a structure.

   A flag flapping in the wind experiences the external forces of the wind and of the connectors tying it to the flagpole. Internally, the fabric experiences stresses due to tension, compression, shear, and torsion as it bends and twists and strains against the flagpole ties. The strongest forces act on the end of the flag. This is where material usually starts to fray.

5. a. Steel has high tensile strength because its particles are arranged in a regular pattern and are very strongly attracted to each other.

   b. Graphite is an excellent dry lubricant because of its low shear strength. Graphite particles are arranged in layers and have very weak attractive forces between them. They tend to slide easily past one another.

   c. Rubber has a high torsion strength because its particles are not arranged in a particular pattern and are strongly attracted to one another in all directions. This allows rubber particles to maintain their bond even when a piece of the rubber is twisted out of shape.

6.

Forces Acting on Bicycle Parts			
Letter	**Part**	**Force Acting on Part**	**Type of Strength Needed**
A	handlebars	torsion	torsion strength
B	seat post	compression	compressive strength
C	spokes	tension	tensile strength
D	pedal bolt	shear	shear strength
E	tire	tension	tensile strength

7. Check your responses with your teacher or home instructor.

8. **Textbook questions 1 to 5 of "Topic 4 Review," p. 314**

   1. Examples of deformation are bending, crushing, stretching, and twisting.

   2. Compression, tension, shear, and torsion are the types of stress that can occur inside an object.

   3. a. A live load is a temporarily applied load. It may be a moving or variable force acting on a structure.

         A dead load is a continuously applied load. It is constant in its position and magnitude (size), such as the weight of the structure and any permanently attached equipment.

      b. Wind is a live load, the weight of the tree is a dead load, and the weight of a bird in the tree is a live load.

   4. a. tensile strength
      b. shear strength
      c. torsion strength
      d. compressive strength

   5. A chewed piece of gum can withstand internal forces much better than a dry stick of gum. The dry stick of gum breaks easily when tension or torsion forces are applied; it can withstand compressive forces better. A chewed piece of gum has greater tensile, torsion, and shear strength than the dry stick.

Section 2: Lesson 3

1. Shear damage is most likely to occur along microscopic cracks and weaknesses in a material.

2. Compressive forces cause a structure to buckle.

3. Ribs and stringers are added to the design of structures to prevent shear, bend, buckle, and twist failures.

4. a. Useful applications of buckle failure in materials are as follows:

      - Crumple zones of automobile bodies, bumpers, and fenders buckle to absorb some of the energy of an impact.

      - Blades of grass buckle to absorb the impact of an athlete landing on the turf.

      - Some packing materials are designed to collapse when a significant force is applied to protect the contents.

   b. Useful applications of shear failure in materials are as follows:

      - Shear pins are used to attach propellers and pulleys to drive shafts. The pins break before other parts of a motor or machine are damaged due to an abrupt stop.

      - The clutch in an automobile is designed to let parts slip by one another.

      - Automatic transmissions are also designed to allow parts slip past one another.

c. Useful applications of materials under stress due to twist are as follows:

- Cotton and wool fibres are twisted into yarn so that it is stronger than the individual fibres.
- Twisting string and wires produces ropes and cables that are stronger than the original material.

5. **Textbook questions 1, 2, and 3 of "What Did You Find Out?," p. 318**

1. Bending tends to fatigue metal sooner.

2. The paper clip warms up at the point where it is being bent. This is the result of the mechanical work involved in bending being transformed into thermal energy.

3. Bending the paper clip puts one side of the clip under tension and the other under compression. After being bent several times, the clip breaks due to tension as the metal particles are pulled apart.

6. **Textbook questions 1 to 5 of "Topic 5 Review," p. 319**

1. a. Answers will vary.

Dead loads in a classroom include the walls, floor, ceiling, any permanently attached shelves and laboratory benches, sinks, light fixtures, electrical outlets, bulletin boards, and chalkboards.

Live loads in a classroom include students, the teacher, any furniture not permanently fixed (desks, chairs), books, laboratory equipment, photographs, posters, and paintings.

b. A dead load is a continuously applied load. It is constant in its position and magnitude (size), like the weight of the structure and any permanently attached equipment.

A live load is a temporarily applied load. It may be a moving or variable force acting on a structure.

2. Materials fail by

- bending caused by tension and compression
- buckling caused by compression
- shearing caused by compression
- tearing caused by tension
- twisting caused by torsion

3. a. Frame structures are most likely damaged by lever action.

b. Mass and shell structures do not have long, rigid parts that can act as levers.

4. a. compression or buckling failure of carpet fibres

b. torsion or tension failure of ligaments in the ankle

c. shear failure of the glass

d. buckling failure of the paper fibres

e. torsion failure of the metal

5. Answers will vary. Three sample answers are given.

   - My friend helped me tear down a tree house (a frame structure). We applied tension on the nails until they came out of the wood. One of the boards suffered shear failure and broke while being pulled from the frame. We dropped the boards to the ground, which was too soft to withstand the compressive forces, leaving several small holes in the turf. We looked for some rope to lower the boards with, but only found some string. The string did not have sufficient tensile strength to withstand the weight of the boards.

   - I ripped the gift box, a shell structure, easily apart. The box material had a very low shear strength.

   - Our snow fort, a mass structure, could not handle the compressive force when I climbed on top. It collapsed.

Section 2 Review

1. **Textbook question 1 of "Reviewing Key Terms," p. 320**

   1.

   (a) K I L O **G** R A M

   (b) F O **R** C E

   (c) F O R C E D I **A** G R A M

   (d) L I **V** E L O A D

   (e) W E **I** G H T

   (f) **T** O R S I O N

   (g) I N T E R N **A** L

   (h) N E W **T** O N

   (i) T E N S **I** L E

   (j) C O M P R E S S I **O** N

   (k) T O R S I O **N**

2. **Textbook questions 2.a., 2.b., 2.c., and 5 of "Understanding Key Concepts," p. 320**

   2. a. F   b. M   c. M

   5. a. Compression is stressing the top of the bookshelf.

      b. Tension is stressing the bottom of the bookshelf.

      c. If books continue to be added, one of two things might occur. The shelf may bend enough to slip past its supports and crash to the floor; or the shelf may suffer tension failure and break. The result is the same, the shelf and books fall to the floor.

Section 3: Lesson 1

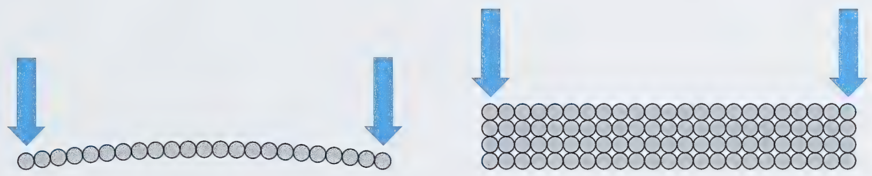
1. Designers rely on one of three key methods to help structures withstand forces:

    - Distribute the load throughout the structure so no single part carries most of the load.
    - Direct forces along angled components that hold pieces together.
    - Shape parts to withstand the specific type of force they are likely to experience.

2. An advantage of a rectangular frame structure is that it is easy to construct. A disadvantage is that applied forces can easily push or pull the rectangular frames apart.

3. Triangular shapes in a frame structure are stronger and cannot be pushed or pulled apart.

4. The ruler on edge has many more rows of particles resisting the tension and compression forces than when it is on its flat side.



Flat Ruler **Ruler on Edge**

5. The keystone of an arch is wedge-shaped. This shape directs forces along the stones of the arch toward the ground.

6. A *cantilever* is a structure that is supported at one end by a strong column and hangs free at the other end. The structure may be as simple as a board or be as complex as a bridge. Examples include diving boards, shop signs, bookshelves, bridges, cranes, airplane wings, and balconies.

7. The shape of these beams requires less material than a solid beam, making it lighter and yet as strong.

8. The "flying buttress" supports high exterior walls of stone structures. This structural feature was developed at a time when the available materials and building techniques required this type of support.

9. Check your responses with your teacher or home instructor.

10. The finishing nail has the least friction with the wood; the screw nail has the most friction with the wood. The ringed nail has less than the screw nail because it is smaller.

11. The "good news" is that friction forces hold the nails in the wood. The "bad news" is that the same forces oppose driving them into the wood.

12. Too little friction in the tuning pegs of stringed instruments causes them to go out of tune.

13. **Textbook questions 1 to 4 of "Evaluate," p. 327**

1. Specifications may have met. However, it is possible that the structure blows over or that the windmill does not turn.

   Blowing over may be prevented by

   - adding a counterweight
   - making a broader base for the tower
   - making the joints more rigid by securing them with pins or clips
   - increasing the mass of the base to lower the centre of mass

   Make the windmill turn in the wind by

   - increasing the size of the blades
   - improving the axle attachment so that it can turn freely

2. The fixed joints are at joints connecting tower parts and at the attachment of blades to the axle. Pins and clips in straws are used to keep joints rigid and durable. Tape and pins keep the axle and blades together.

   The mobile joints are at the attachment of the axle to the tower. Straws and tape hold the axle so it can rotate.

3. The dead load is the weight of the tower (including the propeller).

   The live load is the varying force of the wind on the tower and propeller. The structure can be made strong enough to handle these loads by making fixed joints rigid. A counterweight may help withstand the live load.

4. a. Friction is a force at the joints and between the structure and the moving air around it (wind resistance).

   b. Friction helps at the fixed joints and is negative at the mobile joints. The sideways force due to the wind on the tower threatens the tower's stability.

   c. Increase the friction at the fixed joints. Friction can be increased by making the joints fit more tightly. A filler material can be placed within the joint. A sticky material may also be used to increase friction.

   d. Decrease friction at the mobile joint (of the axle and its support). Apply oil, grease, or any other lubricant to decrease friction.

14. Check your responses with your teacher or home instructor.

Section 3: Lesson 2

1. In Figure 4.61, the mass of the skaters must be uniformly distributed about their vertical axis. An uneven distribution will cause them to fall.

   In Figure 4.62, the masses of the structures are uniformly distributed and held in place by the compressive nature of the force of gravity acting on them.

2. **Textbook questions 1, 2, and 3 of "Procedure," p. 330**

   1. a. The baseball player is in a more stable stance.

      b. The baseball player's feet are spread further apart than the dancer's, making the area of her base of support larger.

      c. Objects with a larger base of support are more stable than those with a smaller base of support.

   2. a. The sumo wrestler is in a more stable position.

      b. The wrestler's hips are closer to his base of support than the gymnast's.

      c. On stilts, your hips are raised higher and your base of support is smaller than when you balance on your feet.

   3. a. The wide stance increases stability (as in the case of the baseball player), and the low body mass also increases stability (as in the case of the sumo wrestler). Two keys to stability are large area of support and low body mass.

      b. A pencil balanced on its point has a very small area of support, base, and most of its mass is very high. A shorter pencil would be more stable but still difficult to balance because of its very small base of support.

3. **Textbook questions 1 and 2 of "What Did You Find Out?," p. 331**

   1. All the lines pass through the point where the object balances on your finger.

   2. The force of gravity acting on the object acts through this point, making it possible to balance it at this point. The point through which the resultant force of gravity acts on an object is the centre of gravity.

4. In addition to your original answer you might want to add the following:

   The skaters have a very high body mass and small base of support; they are quite unstable. The hoodoos are more stable because of their wide base of support and relatively low body mass.

5. The line from the chimney's centre of gravity to the centre of Earth falls outside the base of support. This causes the chimney to rotate and fall.

6. **Textbook question "Pause and Reflect," p. 333**

   In Figure 4.67A, the gravitational force acting on the load (its weight) makes the crane unstable. The counterweight on the other end of the boom balances the load.

   In Figure 4.67B, the mast and booms are top heavy. The gravitational force acting on them makes the structure unstable. The guy wires stabilize the mast and booms.

   In Figure 4.67C, the force of the wind acting on the sail and the buoyant force of the water make the boat unstable. The gravitational force acting on the sailors (their weight) balances the action of the wind and water.

   In Figure 4.67D, the gravitational force acting on the mushroom could unbalance the top-heavy structure. The symmetric distribution of the mass of the mushroom balances the gravitational force. The mushroom's centre of gravity is located in the stem.

7. Check your responses with your teacher or home instructor.

8. Pilings are designed and constructed to support the weight of a structure. They are used in locations where a lot of loose soil exists. Pilings transmit the weight to the bedrock beneath.

9. Packed gravel is used as the foundation for mass structures like roads and dams.

10. Footings are wider than foundation walls to spread the weight of the structure over a larger area. This reduces the stress on the soil below.

11. and 12. Check your responses with your teacher or home instructor.

13. Spin stabilization is used in riding a bicycle, throwing a football or a Frisbee™, using a gyroscope in navigation, and spinning a toy top or yo-yo.

14. **Textbook questions 1, 2, and 3 of "Topic 7 Review," p. 340**

    1. a. Dry soil is more stable than wet soil.

       b. Bedrock is more stable than loose soil.

       c. Balanced forces are more stable than unbalanced forces.

       d. An arch with a tie beam is more stable than an arch without a tie.

       e. A rapidly spinning wheel is more stable than a slowly spinning wheel.

    2. Answers will vary. Sample answers are given.

       a. A tree root grew under the sidewalk and pushed it up. Or moisture in the soil under the sidewalk froze, pushing it up.

b. The subsoil was not well-compacted before the driveway was paved. Or the foundation layer of gravel was not packed. Or groundwater or water leaking from a sewer washed soil particles away, leaving a cavity under the driveway.

3. The logs helped spread the load over a larger area so the swampy ground was able to support it. The gravitational force acting on the load was supported by the buoyant force acting on the logs.

Section 3 Review

1. **Textbook questions 1 of "Reviewing Key Terms," p. 341**

   1. Answers will vary. Sample answers are given.

      a. Pilings are used to transmit the weight of a structure to bedrock in places where unstable soil conditions make the use of footings impractical.

      b. The stability of a structure is improved when all forces are balanced.

      c. Resistance to a nail being driven into a board is largely due to friction between the nail and the material.

      d. Footings spread the load over a larger area.

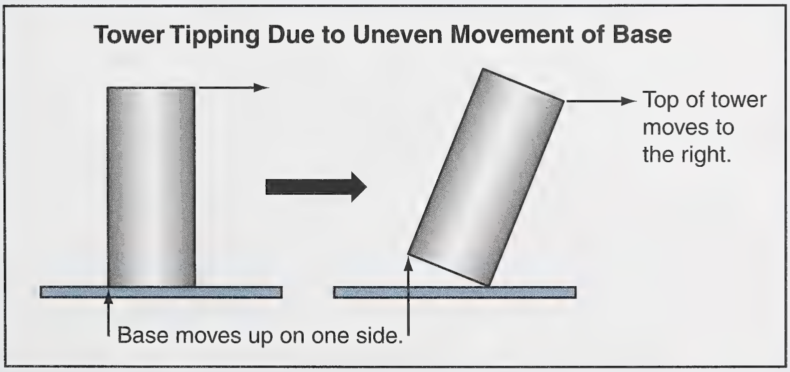
      e. Spin stabilization keeps a gyroscope pointing in the same direction.

      f. Using a brace between a wall and the bottom of a beam increases the load-bearing capacity of the beam.

      g. A stable structure depends on a solid foundation.

2. **Textbook questions 3 to 7 of "Understanding Key Concepts," p. 341**

   3.



4. Friction allows fasteners to hold different parts of a structure together. The greater the friction, the better the fasteners work. However, friction also opposes the fasteners, such as nails and screws, from being driven into materials. Finishing nails have smooth surfaces and are easy to drive into wood; but they do not hold parts together as well as spiral nails or screws.

5. In diagram A, the centre of gravity is located halfway between the children and above the fulcrum.

   In diagram B, the centre of gravity is located closer to the adult and above the fulcrum.

6. Structure A is more stable because it has a broader base and a lower centre of gravity than structure B.

7. A designer looks for a solid foundation, the location of the centre of gravity, the plumb line, balanced forces, and symmetry to ensure a stable structure.

Module Review

1. **Textbook questions 1, 4, 5, 9, 10, 11, 13, 19, and 20 of "Understanding Key Concepts," p. 346 and 347**

   1. A mass structure is usually solid and constructed by piling up materials. Its strength lies in the amount of material, and its weight compresses the ground below. Some examples are dams, roads, snowdrifts, and sand dunes.

      A frame structure has individual parts that are joined to form a skeleton-like structure that supports other parts and the intended load. It requires less material and has more room inside. Some examples are houses, vertebrate skeletons, and cantilever bridges.

      A shell structure consists of a thin shell and has no internal frame. Its shape is its strength. A force applied anywhere is spread over the entire structure. Its weakness, however, is that it cannot resist a force applied to a very small area. Some examples are eggs, helmets, and bowls.

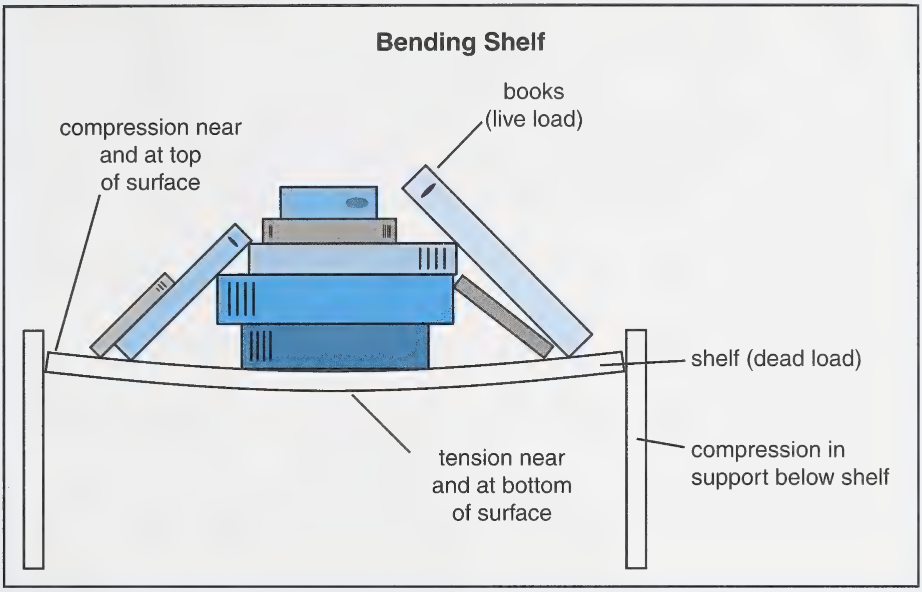
   4. The five basic ways of fastening structures are by using

      - nails (e.g., used to hold a house frame together)
      - ties (e.g., shoelaces)
      - interlocking shapes (e.g., the folded seams used to keep furnace ducts together)
      - adhesives (e.g., various glues holding two pieces of material together)
      - melting (e.g., welded and soldered joints, like in automobile joints and plumbing)

   10. Your weight, the force of gravity acting on your body, is an external force. Compression on the chair legs and the top of the seat are internal forces acting on the chair. Also, tension on the bottom surface of the seat is an internal force acting on the chair.

11. Mass is the amount of matter in an object. It is measured in kilograms and does not change. Weight is the force of gravity acting on a mass. It is measured in newtons and depends on where the mass is located.

13. Diagrams will vary a bit. A sample diagram is given.



20. a. Tension pulls material particles apart.

    b. Compression pushes material particles together and can cause buckling. It also combines with tension to cause bending.

    c. Torsion pushes material particles together in one area and pulls them apart in another area at the same time.

2. **Textbook questions 25 and 27 of "Developing Skills," pp. 347 and 348**

25. The triple-beam balance is used to measure an object's mass. It is calibrated in grams and kilograms. The object is placed on the pan, and sliders of known mass are moved along the calibrated beams until the free arm of the balance lines up with the marker. This indicates that the sliders are balancing the unknown mass. The mass of the object is then read off the beam scales.

    The spring scale (or force meter) is used to measure a force in newtons. You can find an object's weight by hanging the object from the hook and reading the scale. To find the force required to move an object, attach it to the hook and pull the object and then read the scale while the object moves.

27. a. How do the area of the base and the firmness of the soil affect how far a uniform force drives a dowel into the soil.

    b. The manipulated variable is the area of the base of the dowel. The responding variable is the depth the dowel sinks.

    c. The controlled variables include the size of the force, how the force is applied, the mass of the dowels, the surface of the dowels, and the type of soil.

    d. The smaller the area of the dowel and the looser the soil, the further the dowel sinks into the soil when struck with a force.

3. **Textbook questions 29 and 32 of "Problem Solving/Applying," pp. 348 and 349**

29. a. Simple structures include a plastic bag sealed with tape, a waterproof bag, or a plastic container with a lid.

    b. More complicated structures include a cedar chest with a good seal.

32. a. A concrete footing wider than the wall is recommended because it is stable, strong, and easy to build.

    b. Pilings driven into the lake bottom is recommended because it will support the dock and resist wave action. Protecting the pilings from ice with skid plates is also recommended.

    c. Posts (wood or steel) with concrete footings to distribute the load is recommended because it is strong and easy to build.

    d. Compacted layer of sand and gravel is recommended because it does not retain water, provides good support, and is easy to build.

4. **Textbook questions 34, 36, and 38 of "Critical Thinking," p. 349**

34. a. Chairs built from pieces of wood or steel covered with soft material are frame structures. Chairs built from a single solid piece of foam plastic are mass structures. Chairs built from a single piece of molded plastic are shell structures.

    b. Frame structures use less material and are likely more comfortable. However, they can fail at the joints.

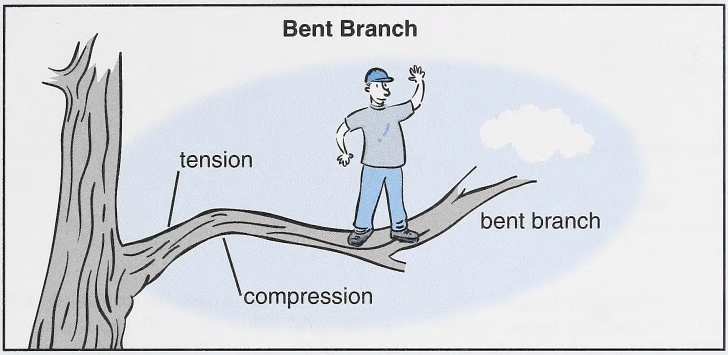
    Mass structures use a great deal of material, but they are stable.

    Shell structures are lightweight and have no joints that can fail. However, they are not as strong.

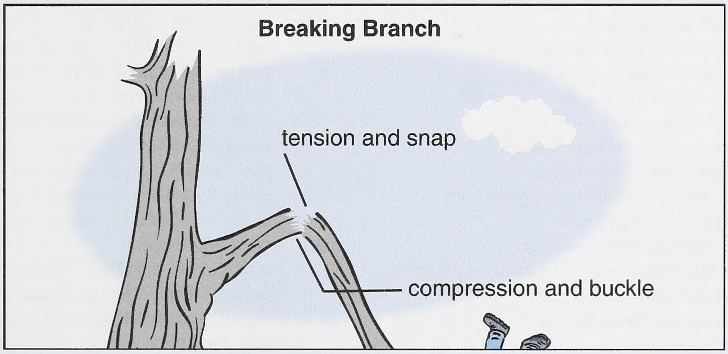
36. Balances compare the gravitational force acting on the unknown mass of an object with that acting on known masses. If gravity is very weak (far from Earth), it is difficult to make this comparison.

38. a. The branch gets thinner as you move further from the trunk and, thus, less able to withstand internal stress.

b. The diagram should indicate tension on the top and compression on the bottom of the branch.



c. The top snaps and the bottom buckles because the top is under tension and the bottom is under compression.



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